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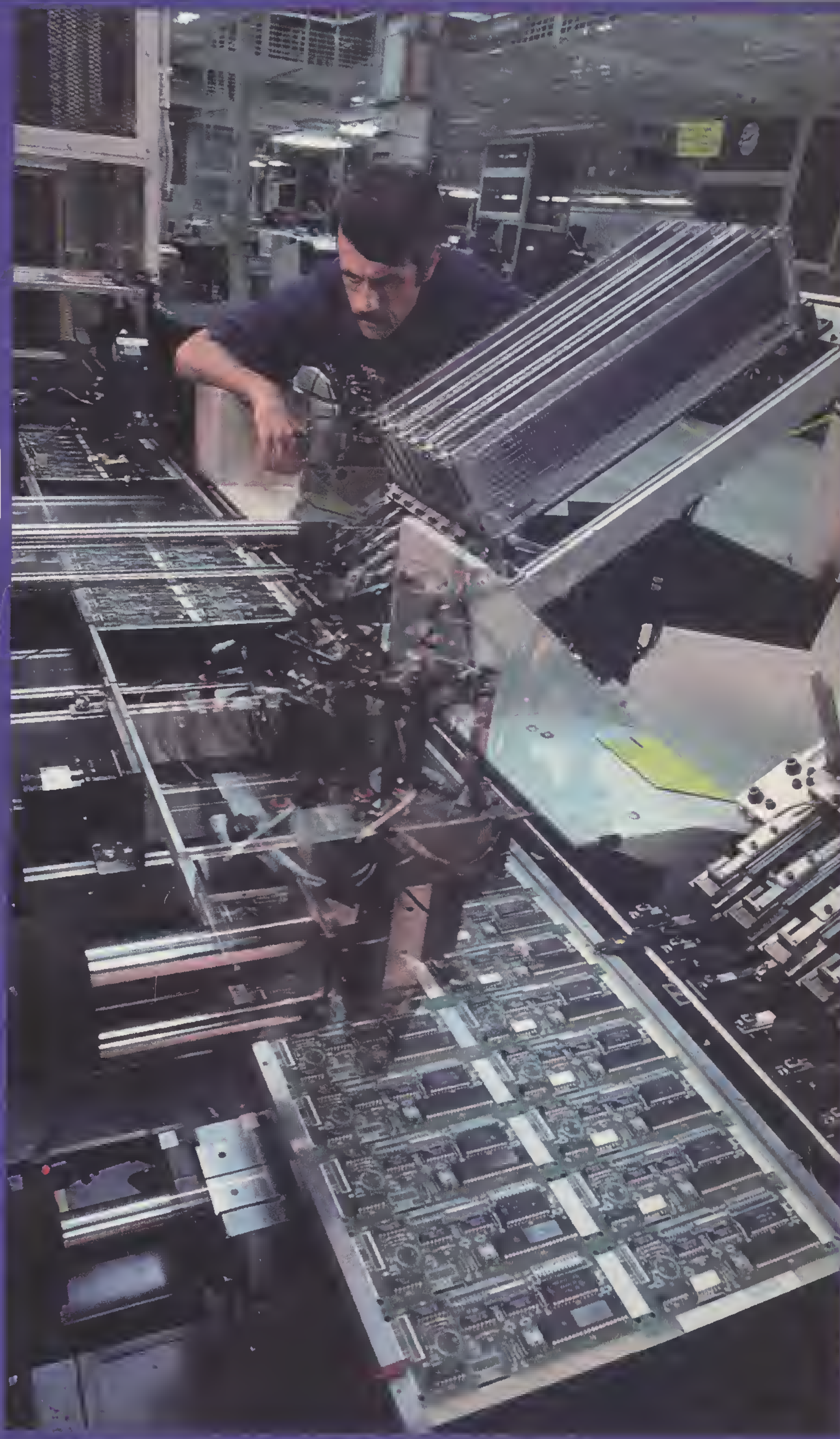

Special report

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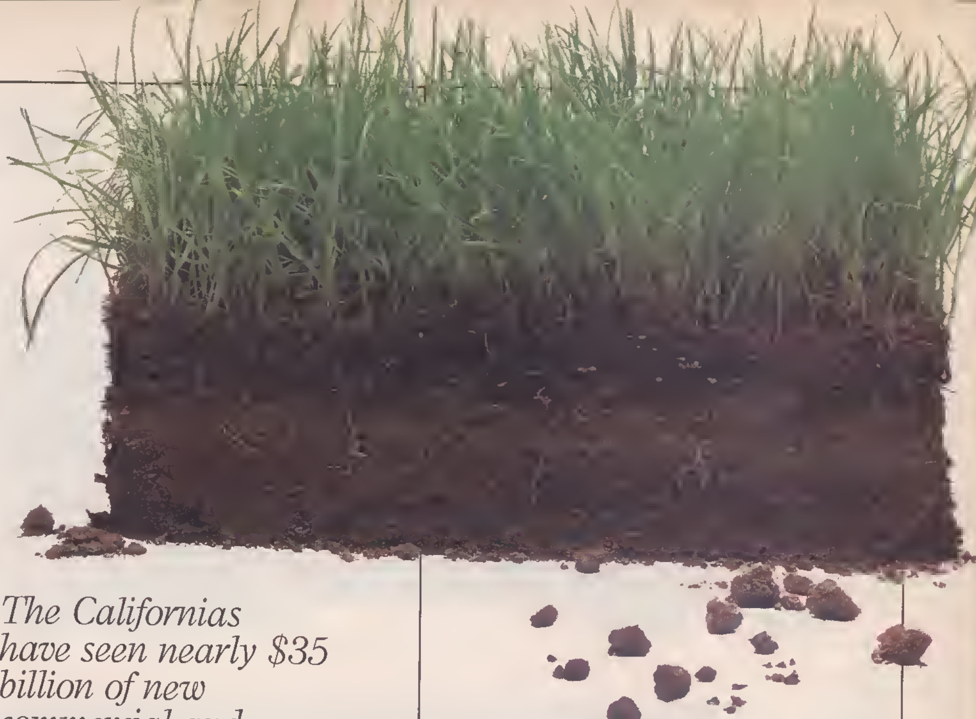

Californians bought more retail goods in 1985 than Texas, Arkansas, Louisiana, and Oklahoma. Combined. Over $160 billion. (That's up 40% from 1980.) The state's total personal income for 1986 is forecast to grow 20% faster than the rest of the nation.

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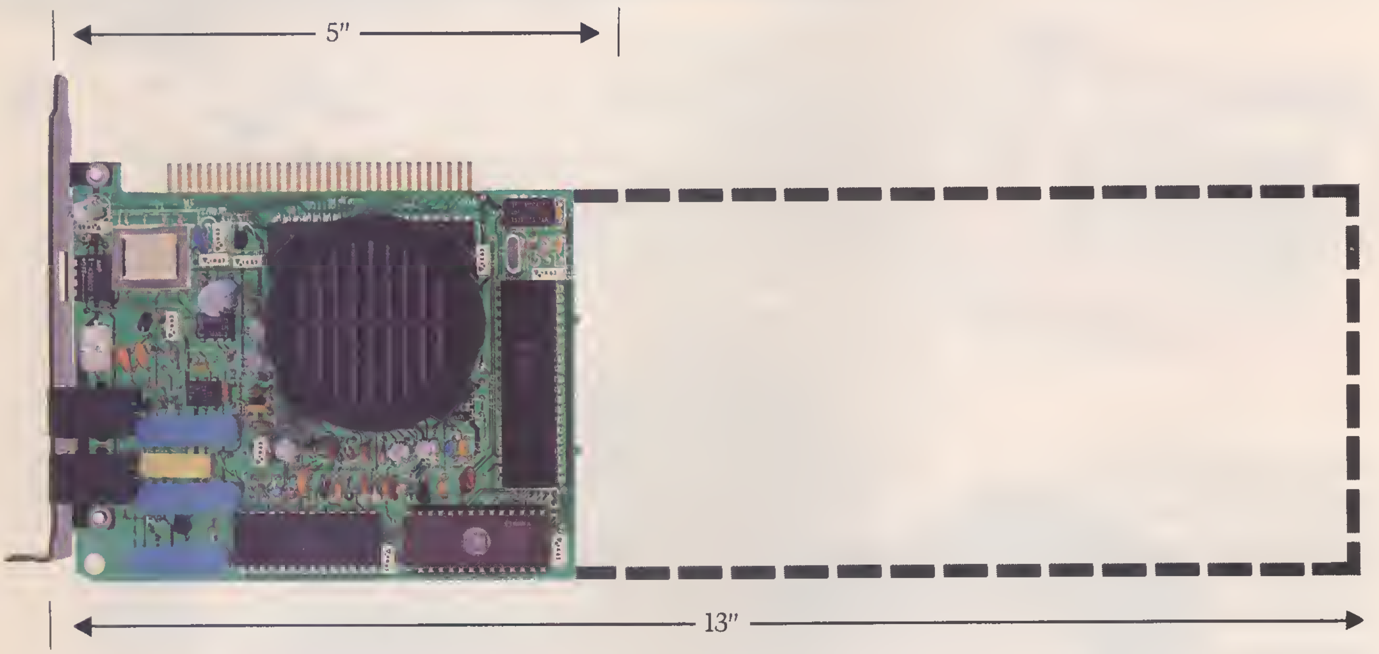

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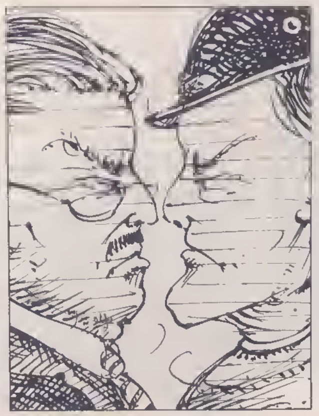
FEATURES

DEPARTMENTS

Cover Automatic inserters assemble control cards at IBM's printer/typewriter plant in Lexington, Ky. Photo by Bill Ballenburg.

OPINION



MARK STEELE

Technology can't solve factory woes without a change in attitudes

Most American manufacturing plants are no longer sweatshops run by robber barons. One reason is a long history of battles pitting management against labor unions. Over many decades labor won concessions in work rules and benefits along with better wages. But despite vastly improved working conditions, this confrontational style of American labor relations still exists.

Consequently, many managers initially saw automation as a potential substitute for troublesome workers; robots didn't take days off, require health benefits, or present grievances. Workers recognized management's intentions and, understandably, resisted the trend. The result: delays in automating.

Today, managers in many industries finally realize that robots and automated machines are not panaceas. They now know that it's difficult to do a good job of automating factories, and that skilled people are essential both to get them going and to operate them successfully. Many unions are now urging modernization. They recognize that if workers don't become more productive their plants will shut down altogether as global competitors with much lower wage rates take over the markets they serve. But for some industries, it may be too late.

While the United States dilly-dallied over automation, other nations were rapidly installing advanced technology. Many of the most successful automation projects are in Europe and Japan.

Unfortunately for the U.S., there are no quick fixes. Recently a few American companies have rushed into total automation systems without gaining experience and skills from a more gradual buildup, sometimes with disastrous results. For many industries, even protectionism may only be staving off the inevitable. In cases where the U.S. does turn to trade barriers to help a threatened industry, there is no attempt to ensure that the profits and time gained are invested to increase competitiveness. Some manufacturers build new plants overseas, or use their capital to diversify.

Granted, some American manufacturers, such as IBM, John Deere, and Nucor Steel, recognize that to retain the skills that provide their market edge they must maintain strong manufacturing operations in the U.S. They see advanced technology as the best way to stay competitive.

Yet technology alone can't do the job. A new compact between management and labor must be built on mutual trust and unified goals. Organizations need to cut out the flow of misinformation, especially from middle management to top management, which too often has resulted in a loss of contact with what's really happening in the factory. Workers need to ease their work rule strictures, while gaining a portion of the financial payoff that can come from well-automated plants. In keeping American industry competitive, better attitudes will be even more vital than better robots.

Robert Haavind

Robert Haavind

highTechnology

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Published monthly by ***High Technology Publishing Corp.***, 38 Commercial Wharf, Boston, MA 02110.

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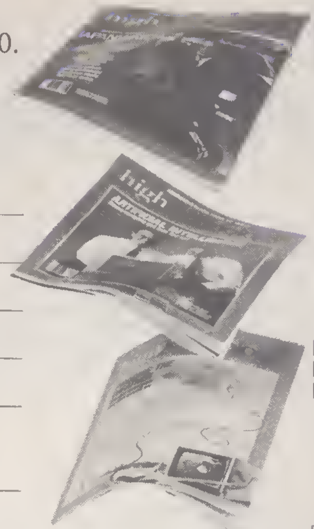

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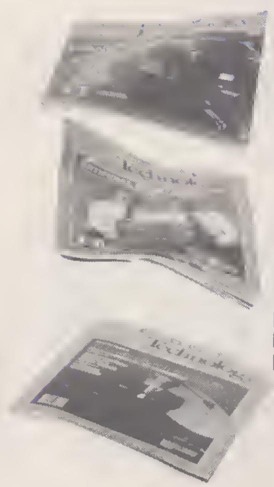

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LETTERS

Eyes on Japan

As long-time Japan watchers, we congratulate you on your excellent report "Japanwatch '86" (Aug. 1986, p. 20).

We're marketing professionals specializing in aiding vendors to the information systems and manufacturing sectors, and have frequently criticized the American propensity for quick-profit, technology-pushed investments. Your succinct report on Japan highlights the relevance of demand-pull.

Stephen J. Nagy, President
Strategic (Management) Systems
Bedminster, N.J.

"Japanwatch '86" scares me to death! Your accompanying editorial, "The very model of a modern major competitor," is right on the mark. The Japanese are efficiently practicing a form of what we used to call Yankee ingenuity. Why is it that almost all new products seem to be coming from Japan? I keep wondering where our inventors and engineers are.

Robert Underbrink, Head Librarian
Lumpkin Library
Blackburn College
Carlinville, Ill.

Industrial funding of academic research

Your Opinion "Ivory towers offer golden opportunities" (June 1986, p. 4) and the letters from Drs. Vandiver and Mujumdar ("Industrial support of research universities," Aug. 1986, p. 5) support industrial funding of academic research in the same way that everyone supports liberty: it's great in principle. But what about the specifics?

Enlightened and giant companies such as IBM and Hewlett-Packard have the resources to support academic research, but it is very difficult for small and medium-size companies to do so. The main reason is that ubiquitous bogeyman called overhead. In addition to the money a company must pay the researchers, it must pay the university an additional lump sum of one-third to often over 100% of the direct costs. Small companies just cannot afford to pay $2 for every dollar's worth of research.

There are plenty of good universities competing for industrial money; the free-market system will, hopefully, push down the cost of overhead.

Lawrence P. Kunstadt, President
Barrington BioIndustries
Great Neck, N.Y.

Your Opinion on industrial/educational partnerships was most welcome. You may be aware of Pennsylvania's Ben Franklin Partnership, in which both large and small companies are working with a broad base of colleges and universities to apply advanced technology to the state's industries.

For example, the North East Tier Ben Franklin Advanced Technology Center—one of four advanced technology centers established by the partnership—works with a consortium of 447 companies, 69 schools, and 72 other organizations throughout northeastern Pennsylvania.

Mary Frances Donley
Public Information Coordinator
NET Ben Franklin Technology Center
Lehigh University
Bethlehem, Pa.

Company managers attend Ben Franklin seminar on CAD technology at Lehigh lab.

Technology in Alabama

We were disappointed on reading "Businesses take root in university parks" (Jan. 1986, p. 40) to discover no mention of Huntsville's Cummings Research Park, since it is older and has more acreage, tenants, and employees than do most of the parks cited. Cummings boasts 3700 acres occupied by over 40 corporations and federal agencies, as well as a campus of the University of Alabama (UAH). Park employment exceeds 12,000 persons. Among Cummings's tenants are Chrysler, AVCO, Teledyne Brown, Rockwell International, Hewlett-Packard, GE, Motorola-UDS, IBM, SCI, Sparta, BDM, Lockheed, TRW, United Space Boosters, New Technology, McDonnell Douglas, the Army Strategic Defense Command, and the Army Corps of Engineers Training Center.

Cummings Research Park has been selected as the home for Alabama's supercomputer that should be operational by 1987, and the UAH Center for Applied Optics has been named a Strategic Defense Initiative center of excellence for high-speed optical computing.

In a 1985 American Federation of Scientists' study, Alabama ranked second only to California in SDI contract dollars. Of Alabama's $355 million, the overwhelming majority has been awarded to firms located in Cummings Research Park.

As home of NASA's Marshall Space Flight Center and Redstone Arsenal, Huntsville has a distinguished history as a high technology center.

Dallas W. Fanning, Planning Director
City of Huntsville
Huntsville, Ala.

Biotech in the limelight

If success in the aftermarket is one measure of a company's performance, then the same must be true for a periodical. Our company was very impressed with your fine article "Building a better tomato" (May 1986, p. 46). In the past few months, your article has proved a tremendous catalyst—stimulating a great deal of interest in our company from the brokerage community and the media. We have been fortunate in receiving a great deal of positive media attention in the past few years, but it seems that no other article has prompted the interest that yours has.

Richard Laster, President
DNA Plant Technology
Cinnaminson, N.J.

Unacceptable RISC

I found "A simpler path to computing" (June 1986, p. 28) to be well below your usual standards of clarity and sophistication. For example, I don't think you coherently supported your contention that it is easier to write an optimizing compiler for a RISC [reduced instruction set computing] machine. The complexities of CISC instruction sets like the VAX's were in fact designed to simplify the compiler's job, not to capriciously complicate it. You also ignore the countertrend toward specialized CISC processors such as LISP machines and vector-processing supercomputers.

The real common sense is this—a computer system will run efficiently if frequent operations run quickly and do not aggravate the memory-CPU bottleneck. In a CISC machine, this means placing certain common but complex operations in hardware, usually fast microcode. On the other hand, the RISC designer tries to optimize elementary operations.

Jonathan Eckstein
Arlington, Mass.

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110.

Fiber optics: beyond 20,000,000,000 bits/sec.

Summary:

GTE scientists have demonstrated laser modulation and detection at rates as high as 20 gigabits/second. They have developed ultra-small lasers that have light emitting areas as small as 0.2 square microns. They are working to improve the glass fiber itself, as well as to produce optical analogs of electronic switches with the long-range goal of all-optical systems, in which message streams are switched as much as 10,000 times faster than at present.

GTE commercial involvement in fiber optics communications systems dates from the first such installation in Artesia, California, in 1977.

Our scientists developed the system's technology and equipment, and have been contributing to the state of the art ever since.

Current projects deal with increasing the capacity, the versatility, the applications of the systems; longer-term, we are exploring the possibility of all-optical systems.

Faster and faster...

Until recently, optical systems processed digital streams at speeds ranging up to hundreds of megabits per second.

Fast though that may seem, today's carriers are seeking speeds in the gigabits-per-second range. This might even permit the glass to be brought directly to satellite earth stations or microwave towers, for example, for direct conversion of radio signals to light.

Recently, GTE demonstrated the ability to turn diode lasers on and off at rates as high as 20 gigabits per second—about 333% higher than the greatest previously recorded speed.

...and smaller and smaller.

Such speeds require very special lasers. And, as you can see from the electron micrograph at upper right (the head of an ant looking at one of these lasers), it is extremely small.

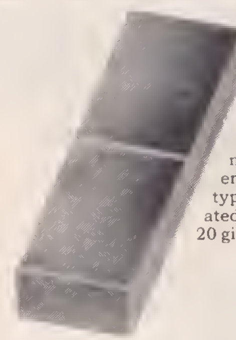
It was constructed on a wafer of InP, by epitaxial growth of a layer of InGaAsP approximately 0.1 micron thick. This was then etched to a mesa shape, and further layers of InP added.

The resulting laser cavity is approximately 0.2 square micron in area, and provides an excellent mate for single-mode glass fiber (fiber with a core of such small diameter that light travels a single path—mode—drastically lowering its dispersion within the fiber).

Switching light with light.

In another project, we are investigating the possibility of ultimately eliminating the electronics altogether by using optical switches.

We are working with materials whose indices of refraction vary with the intensity of incident light—a non-linear response.



Head of an ant dwarfs a sub-micron-sized diode laser in this electron micrograph. GTE scientists developed this type laser, and have operated it at rates as high as 20 gigabits a second.

Ultimately, if it actually does become possible to switch systems optically, an improvement in speed of as much as 1,000,000% is theoretically possible.

In its brief history, fiber optics has made astonishing strides. At GTE, we are working to continue at the frontiers of this science—to make fiber optics an even more helpful technique to meet the endless needs of tomorrow's telecommunications.

The box lists some of the pertinent papers GTE people have published on various aspects of fiber optics. For any of these, you are invited to write GTE Marketing Services Center, Department FO, 70 Empire Drive, West Seneca, NY 14224. Or call 1-800-833-4000.

UPDATE

JPL's sprawling facilities in Pasadena, Cal., are now accessible to young technology firms. Inset (left to right): NASA Assistant Administrator Isaac Gillam IV, U.S. Rep. George Brown (D-Riverside), and RIMTech president Steven Panzer convened to announce the program.

Business taps into NASA R&D

Because the high cost of R&D is often the biggest obstacle facing young high tech companies, gaining access to the technology base of a major research lab would appear to be a dream come true. But that's exactly the purpose of a program at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Cal. Under the program—which is administered by the Research Institute for the Management of Technology (RIMtech), a nonprofit organization in Los Angeles—a company first meets with JPL scientists to see how its technical problems match up with the lab's expertise. If the fit looks promising, the company pays RIMtech an annual fee of $25,000, and JPL starts working on solutions.

The program is part of an effort mandated by Congress to make tax-supported research more accessible to industry, says Daniel Schneiderman, head of JPL's space commercialization office, and is the first to focus on entrepreneurial firms. Since a test phase began last February, JPL has been working with several southern California companies. For example, computer maker Alpha Microsystems is trying to increase the capacity of its tape backup storage devices with the help of data compression techniques developed by JPL. And an unnamed company is evaluating the lab's water filtration technology for possible use in systems to filter drinking water.

Gore-Tex variant may help computers run faster

A material very much like Gore-Tex—the lightweight, water-resistant Teflon fiber used in sports apparel—may soon be jogging its way into computer hardware. Printed circuit boards with densely packed very-high-speed integrated circuits (VHSICs) would greatly boost the speed of a computer, but manufacturers have had difficulty making laminates (the layers of conductive material that connect the circuits on a board) suitable for holding the chips' many tiny pins. Now, several computer vendors are eyeing the new Gore-Tex variant from W. L. Gore and Associates (Newark, Del.) as a likely prospect. Sperry Corp., for example, is considering using the material in its next generation of mainframes.

The epoxy-glass laminates used in conventional printed circuit boards don't work with VHSICs; as the surrounding temperature changes, the material expands or contracts faster than the metal pins, cracking the tiny solder joints. The addition of Kevlar plastic solves this problem but makes the laminate so tough that it wears out drill bits quickly.

By contrast, the Gore material expands slowly enough to keep solder intact, and can be drilled easily. A bonus: it also has a low dielectric constant—a property that Gore composites marketer Daniel Johnson says will allow signals to travel faster throughout the board.

Curing paint with light

An industrial painting system that cures with ultraviolet light reportedly uses only a third as much energy as oven curing systems. And while conventional curing often takes 30 minutes, the UV method requires 30 seconds or less, says Edward J. Croop, a researcher at Westinghouse's R&D Center in Pittsburgh, which is offering the system for licensing.

The trouble with oven curing, according to Croop, is that only a fraction of the energy is used to dry the paint; most of it is consumed in firing up the oven, heating the part, and burning off the solvent emissions. But in the UV method, he says, the radiation is absorbed entirely by the coating.

The system consists of radiation-polymerized resins, which harden in response to light, a photoinitiator (the light-sensitive chemical that starts the process), and pigments whose UV transmission characteristics are matched to the wavelength of the lamps. Because there are no solvents—the solids content is 100%, versus

UPDATE

50% for most coatings—there are no pollutant emissions.

The paint, which is applied with a brush or spray gun, can coat any object that now uses oven curing, such as auto parts. And since it requires no heat, says Croop, it could cover plastics and other materials that can't withstand high temperatures.

Weather monitor promotes airport safety

Every year, almost 1000 accidents involving general aviation—business and private aircraft—are blamed at least partly on weather. One reason is that only about 800 of the more than 6000 airports in the U.S. have weather-reporting services, and many of those operate only part-time. To alleviate the problem, the FAA in April proposed tough specifications for automated weather observing systems (AWOSs). Already, the first AWOS has been certified and put on the market.

The system, built by Handar (Sunnyvale, Cal.), provides literally up-to-the-minute weather data. Every 60 seconds, its sensors monitor wind speed and direction, temperature, dew point, and barometric pressure near the landing zone. A microcomputer converts the data into a synthesized voice report that pilots can receive over their radios.

Several other companies—including Artais (Columbus, Ohio), Weathermeasure (Sacramento, Cal.), Haynes (Minneapolis), and Cardion (Holtsville, N.Y.)—are vying for a share of the AWOS market, which Handar expects to exceed $150 million within 20 years.

Sensors that monitor cloud cover and height, visibility, precipitation, and runway condition have been submitted for FAA certification. And several companies are working on sensors to detect lightning, freezing rain, thunderstorms, dust, smoke, and haze. Eventually an AWOS might be able to give real-time warnings of wind shear, the deadliest of all landing hazards.

Stronger glass means stronger lasers

Lasers made of glass impregnated with neodymium ions are the most powerful source of near-infrared light. Now, a treatment that makes glass less likely to break when heated promises to triple the power of these lasers, whose 1-micron wavelength has many industrial and medical uses.

Researchers at the U. of Rochester immerse lithium-rich glass in a molten salt bath containing sodium and potassium. Some of the lithium migrates into the bath, and the much larger atoms of sodium and potassium stuff the resulting holes. Consequently, the glass develops a tightly compacted skin that loosens up—rather than breaks—when heat expands the glass, says Rochester ceramic engineer Kathleen Cerqua. This technique has long been used to strengthen plate glass, but previous attempts with laser glass were foiled by a residue that ruined the material's optical quality. To solve this problem, Cerqua spikes the salt bath with powdered aluminum, which drives out the water responsible for the unacceptable residue.

Glass-laser beams are already used to cut and drill metals and other materials. In the semiconductor industry, such radiation could perform x-ray lithography—zapping a metal target to generate an intense burst of x-rays, which would then pass through a pattern mask to image a high-resolution circuit onto a silicon wafer. This technique may eventually become necessary as more and more components are crammed onto chips. But the souped-up glass laser may find its most immediate use elsewhere: the Rochester work was sponsored by General Electric's Defense Systems Division (Binghamton, N.Y.), for undisclosed military applications.

Wall coverings trigger smoke detectors

Smoke detectors give relatively little warning of fires that start inside walls, such as those caused by faulty wiring. But new wall coverings from BFGoodrich (Akron, Ohio) represent an attempt to bridge this safety gap by allowing existing smoke detectors to double as heat sensors.

Goodrich impregnates its fabric-covered vinyl material with a proprietary polymer. When heated, as by a fire in the wall or an adjoining room, the polymer vaporizes. The resulting colorless, odorless gas trips the alarm on any ionization-based smoke detector (by far the most common type now in use). The polymer begins to vaporize at 300° F, well below the ignition point of paper, cotton, and wood, according to Richard S. Varga, who heads fabricated polymer work at Goodrich's R&D Center (Brecksville, Ohio). Heating about one square foot of the material generates enough vapor to set off the alarm in an average-size room, says Varga.

Vinyl wall coverings are used extensively by hotels, hospitals, and offices. Among the first buildings to have installed the early-warning material: the White House. Varga says the company is considering licensing the polymer in a liquid form that could be sprayed or brushed onto walls.

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Seeing the light in manufacturing

Ronald C. Reeve
Chief Executive Officer, Edison Welding Institute

To understand American manufacturing competitiveness and the future of the U.S. economy, first consider the behavior of a fly and a bee in a bottle. A fly bounces furiously from side to side, constantly changing direction. Eventually, it will hit the opening at the top and escape. By contrast, a bee in a bottle always heads toward the light. And unless that light just happens to be above the opening, it bumps over and over against the same side, cannot escape, and eventually dies.

American manufacturing, in the first half of this century, was created by risk takers—the "flies" of the analogy—and until the late 1950s, the U.S. led the world in mass production. But in the 1960s, factories lost their glamour. The risk takers buzzed off to finance and marketing, and gradually a swarm of bees settled over the manufacturing field. We didn't, it appeared, need bright entrepreneurs in manufacturing anymore. Instead, the field attracted people who could singlemindedly keep the machines well lubricated and in working order. Increasingly, industrial engineering jobs were filled by graduates from a hodgepodge of disciplines who gave little thought to the basic problems of turning raw materials into finished products. One result was that university industrial engineering departments, which had produced many of our best manufacturing innovators, all but disappeared.

Only recently have the consequences of this change become clear to American management. Executives have discovered that orders they gave five years ago to automate their production systems, in an attempt to regain a manufacturing edge, have not been carried out. Plant engineers did not know how to do it.

That is why one major aerospace company has just retired most of its manufacturing engineering staff. That is why a leading steel company has just laid off 200 research people and process engineers. The media interpreted these dismissals as decisions not to pursue innovation, but I believe they reflect the realization by executives that their staffs are simply unable to respond to the challenges manufacturers now face.

The trouble with this lost generation of U.S. manufacturing engineers was that they insisted on risk-free solutions. If you brought such an engineer a robot, he would say, "That's interesting, but we have to handle different-size parts. Come back when your robot has a vision system that can distinguish sizes." Such a solution is as logical as a bee heading for the light. As a result, manufacturing remained stuck at the same noncompetitive level, while "solutions" grew more and more complex.

> *The good news: A new generation of manufacturing engineers will lead us back to competitiveness. The bad news: It will take at least five to ten years.*

Meanwhile, Japanese engineers have been attacking manufacturing problems on all levels. Although they, too, are working to develop highly sophisticated automation techniques, they have not hesitated to adopt many less-than-perfect solutions that save money. For example, one robot I observed while visiting a Japanese factory five years ago was so flimsily built it actually shook as it picked up aluminum parts from one conveyor belt and set them on another. It was what engineers describe as a kludge, and I smiled when I saw it. But I was caught short when my Japanese guide said pointedly: "This robot does what it needs to do." With thousands of solutions like that one, so do Japanese factories.

But there is good news. A whole new generation of industrial engineers, more daring than the graduates of the past 30 years, is emerging from American universities. These are the young engineers who grew up playing with computers, and who have now been attracted by the glamour of automation and the challenge of foreign competition.

In turn, they are being recruited by an increasing number of corporations that are giving them unprecedented responsibility. An auto parts company I know of is typical. Although the vice-president of manufacturing is in his late 50s, the engineer in day-to-day charge of manufacturing is only 27 years old. All of the company's older staff has been let go. This phenomenon has led to a bizarre split in the engineering job market: there is a glut of engineers in their 40s and 50s and an insatiable demand for young engineers. A newly graduated welding engineer can expect a starting salary of

The Edison Welding Institute is one of six manufacturing centers created by Ohio's Thomas Edison Program.

$30,000 to $35,000 a year.

Does this mean that we can now relax and let this new generation of manufacturing engineers lead us back to competitiveness? Unfortunately, no. The young engineers have many virtues, but shop-floor experience is not one of them. In many cases, they are attracted to the same complex solutions favored by their predecessors—not because they want risk-free solutions, but because they are dazzled by the technological possibilities of computer-integrated manufacturing.

It will take at least five to ten years before this new generation of engineers can combine its risk-taking attitudes and computer literacy with practical knowledge and thus begin producing enlightened solutions. Meanwhile, state-funded applied research initiatives can play a crucial role. Pennsylvania's Ben Franklin Partnership, Michigan's Industrial Technology Institute, Virginia's Center for Innovative Technology, and Ohio's Thomas Edison Program, among others, can help provide a wide range of potential manufacturing solutions as the new generation of engineers comes of age.

Here's an example: General Dynamics recently suffered repeated inspection failures in a critical weld joining two metal tubes of a space vehicle. The latest electron-beam welding technology failed to do the job. As a solution, the Edison Welding Institute suggested friction welding, a 20-year-old technology that requires rubbing the two pieces of metal until they are hot, then squeezing them together. It is a technology far closer to old-fashioned blacksmithing than modern computerized methods. Yet it worked, and General Dynamics believes its adoption saved $7.9 million.

We have dozens of such practical solutions. At present, however, the only time we can get them into factories is when companies face emergencies. When we try to address more predictable manufacturing problems, our clients usually want to talk only about the latest in electronic wizardry, which we also offer. But we're confident that our young engineering customers will soon learn how to talk about both types of solutions at the same time. Then the U.S. will be on the road to significant improvement in manufacturing productivity. □

BUSINESS STRATEGIES

Tandon:
FROM DISK DRIVES TO PC CLONES

Midway through a year in which IBM watched its share of the PC market being eaten away by clone makers, yet another competitor has plunged into the fray. In July, Tandon (Chatsworth, Cal.), the original manufacturer of disk drives for the IBM PC and PC/XT, announced that it would start selling IBM-compatible PCs in the United States. Tandon first started making PCs in 1984 for resale under other companies' names, but last year decided to shift its overall focus from manufacturing drives to entire computers. The decision was motivated largely by a sharp drop in the company's disk drive business, says president Dan H. Wilkie. A cutback in orders from IBM—overstocked with PCs in 1985 as it faced an industrywide slump—led to an eventual $135 million loss for Tandon that year. To plot a new course into the retail channel with a line of PCs under it's own name, Tandon recruited several ex-IBM manufacturing and marketing executives, including Wilkie, who joined the staff last December.

"You may well ask, who needs another PC manufacturer?" says Sirjan Lal Tandon, chairman and CEO, referring to the recent influx of low-priced clones from Korea and elsewhere in the Far East. While acknowledging that the new entrants have been able to cut prices drastically, he claims that Tandon's India- and Singapore-based manufacturing operations put the company at a similar advantage. And like other technically innovative clone makers, Tandon has further cut manufacturing costs by using fewer, more complex chips to streamline the main circuit boards on its line of IBM PC/XT and PC/AT compatibles. Moreover, Tandon says, the company manufactures its own disk drives, which represent more than 30% of the entire computer's cost. "None of the Koreans make drives," he asserts. "That's the big advantage we have." With plans to start making its own power supplies as well, Tandon will have a vertically integrated manufacturing capability for PCs that almost rivals IBM's own.

Such low-cost manufacturing operations allowed the company to set its computer line's suggested prices 32–46% lower than comparable IBM models and to offer dealers margins some 4–10 percentage points better than those offered by current market leaders, says senior VP of sales and marketing H. L. Sparks. Tandon computers, which were introduced in Europe last November, will be carried in the U.S. by more than 500 outlets of several large computer retail chains, including Entre Computer Centers and Sears Business Systems Centers.

"Tandon has a better chance than a lot of the clone manufacturers because of these attractive dealer margins and its 10-year track record for delivering high-quality products," says Louis Giglio, director of technology consulting for securities brokerage Bear Stearns & Co. (New York). "But they're taking a big chance." Not only is competition among clone makers at an all-time high, he notes, but "you can't expect IBM to stand still either." The computer giant has already lowered its prices more than once in the past year. More significantly, it is rumored to be considering making technical modifications to the PC line that would "make it a lot harder for the clone manufacturers to compete," says Giglio. Given these uncertainties, he speculates that what may prove to be Tandon's safety net is its business as a PC supplier to other computer companies. Xerox, Tandem Computers, and Siemens are currently selling Tandon PCs under their own labels, although Tandy—which has been selling a Tandon-made PC/XT clone—recently severed its ties.

As for the company's own expectations: "We want to be one of the top five PC manufacturers by the end of 1987," says VP Sparks, with an 8–10% share of the market under the Tandon label. That will mean contending with the likes of Compaq, NCR, and "knock-offs from all over the world," notes Giglio. "Still," he says, "Tandon has a better chance than a lot of them."

—Sarah Glazer

Space Structures International:
RAISING CONSTRUCTION TO NEW HEIGHTS

Fifteen years ago Space Structures International (Plainview, N.Y.) began designing and building space frames, the domelike structures of interlocking struts used to support the roofs of office building and hotel atriums and of modern, columnless athletic arenas. The firm soon became a technical leader in the field, helping to pioneer the use of aluminum in place of steel and designing proprietary, adjustable-angle hubs (the joints that anchor struts together), which made greater structural variety possible. It also developed a computer-aided design (CAD) system described by Henry Kelly, director of a building technologies study for the Congressional Office of Technology Assessment, as one of the industry's most innovative. The CAD system integrates design, load analysis, and cost estimation with automatic generation of component lists, assembly drawings, and fabrication instructions for computer-controlled milling machines.

Now, with more than 500 space frames worldwide to its credit and revenues projected to be $15 million this year, Space Structures is looking toward a promising new market—construction in outer space. In 1984, the NASA Langley Research Center approached the firm for help in adapting hub systems to construction of the planned space station. NASA wanted to develop hubs based on a hand-operated latch system Langley engineers had designed that eliminated the need for tools, which are hard to handle in zero gravity. "I was hooked," says Wendel R. Wendel, Space Structures president, "by the challenge of working in space and the potential market." The firm won the hub design contract and created a new subsidiary, Star Net, to undertake the space applications. After the construction system it designed was successfully evaluated at McDonnell Douglas's underwater neutral buoyancy test facility, Space Struc-

Space Structures president Wendel R. Wendel tests construction methods for outer space in an underwater chamber that simulates zero gravity.

tures began supplying samples or designs to aerospace contractors Lockheed, McDonnell Douglas, Rockwell, Boeing, and Grumman.

The space station's current design calls for a 450-foot hub-and-strut spine to which radar, telescopes, solar cells, and the crew's quarters will be attached, says Christopher Roberts, director of venture financing at the Center for Space Policy (Cambridge, Mass.), an aerospace management consulting firm. It is scheduled for construction in the mid-1990s at an estimated cost of $8 billion, although the Space Shuttle's current grounding could push timetables for all U.S. space programs forward, he notes. "Space Structures' manufacturing experience and developing familiarity with space construction requirements" make it a strong contender for a subcontract, says Roberts. "And so far," he says, "none of its competitors have shown much interest in the space market," including chief rival Unistrut.

However, space construction may appear more lucrative with the emergence of a new market, predicts Roberts, which may be far bigger and may materialize even sooner than the space station. The Strategic Defense Initiative (SDI)—if implemented—could include several rotating platforms to house space-based radar and laser systems. Even if SDI does not fully materialize (at a cost estimated as high as $1 trillion), components such as space-based radar installations may still be built, says Roberts, perhaps as soon as 1990.

Space Structures will have to keep abreast of fast-changing technology to stay in the running for such specialized construction, notes Martin Mikulas, a NASA design engineer. For example, NASA is considering making hubs and struts from lightweight composites rather than metal, he says, and wants to develop robot assembly techniques, in light of its estimates that deploying human labor would cost some $50,000 an hour. Wendel reports that the firm is already experimenting with composites and is continually refining its designs. What's more, he is raising additional capital specifically for the Star Net subsidiary, which he hopes will lead to substantial growth. "Space-related contracts account for less than 10% of our business now," says Wendel, "but I expect that share to rise to 50% within five years."

—*Kevin Finneran*

Cetus:
FALLING BACK ON CHEMOTHERAPY

One of the main obstacles hindering the fledgling biotechnology industry is the lengthy evaluation process federal regulatory agencies require to approve new products. Particularly for drugs, toxicity testing and clinical trials routinely add years to product development cycles. However, eight-year-old Cetus (Emeryville, Cal.) has opted not to sit on the sidelines of the cancer drug business while waiting for FDA approval of its genetically engineered cancer treatments. Late last year, it formed a 50-50 joint venture to formulate, manufacture, and market generic chemotherapy drugs with Ben Venue Laboratories (Bedford, Ohio), a contract developer and maker of these conventional cancer treatments.

Cetus–Ben Venue Therapeutics expects to have its first generic chemotheraphy drugs on the market this year, says Cetus president Robert Fildes. (Fildes was formerly in charge of Bristol-Myers's biological and chemical operations and was also briefly president of Biogen.) And more should follow shortly, thanks to an abbreviated FDA procedure designed to foster competition for long-used name-brand drugs once patents have expired.

With Ben Venue to provide manufacturing expertise, Cetus is hiring a sales force that Fildes hopes will "establish the Cetus name among hospitals and cancer clinics well before we go to market with our proprietary drugs." These still-unapproved drugs—eligible for patents because of the proprietary genetic engineering techniques used to produce them—include immune-system regulators such as interferon and interleukin-2 (which

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In addition to its large internal memory blocks (512 × 32 × 2 data RAM, 2K × 32 program ROM and 1K × 32 data ROM), the 77230 provides external expansion up to 4K of program RAM and 8K of data RAM. Serial and parallel I/O also add flexibility. The serial interface allows cascading, links with codecs and AD converters while the parallel interface supports master- and slave-mode operations.

The 77230 is ideal for image processing, graphics workstations, telecom and other applications requiring high speed and high precision.

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NUMBER 135

NEW ZEALAND GOES DIGITAL WITH NEW FOTS AND NEAX61.

Plans for a nationwide Integrated Digital Network (IDN) in New Zealand, where the telephone ownership rate is among the highest in the world, are rapidly taking shape.

The New Zealand Post Office selected NEC to supply state-of-the-art 140MB fiber optic transmission systems (FOTS) and digital switches that will bring the digital future clearly into view.

NEC will provide all the necessary optical terminal and repeater equipment for the fiber optic systems to be installed in links covering Wellington, Auckland, and other major cities.

NEC's 140MB FOTS provides high-quality communications paths equivalent to 1,920 telephone channels. High-performance optical devices enable long repeater span. It also features in-service system monitoring functions, low power consumption and compact size. A slim rack, measuring 2.75m(H) × 0.12m(W) × 0.225m(D), accommodates three terminal systems.

For the development of its ISDN, the New Zealand Post Office selected NEC's enhanced NEAX61 digital switching system with ISDN capability. Nearly 100 systems, including toll and international switches, are to be supplied within a five-year period.

NEAX61 digital switches with an aggregate total of 5 million lines are now in service in 36 countries.

NEC TRANSPONDERS SELECTED FOR INMARSAT-2.

NEC satellite transponders will play a key role in INMARSAT-2, the second generation of international maritime communications satellites.

NEC was recently awarded a contract from British Aerospace Public Limited Company to supply TT&C C-band transponders. This technology-intensive equipment is used to receive and demodulate telecommand signals, to transmit telemetry signals, and for ranging.

The transponder design will include various leading-edge technologies such as low noise amplifiers (Noise figure: 2.5dB), SAW filters to achieve excellent band-rejection performance (60dB min. ±2MHz from center frequency), threshold extension FM demodulation to achieve high sensitivity, and hybrid microwave ICs to minimize equipment size and weight, plus high-efficiency high-power amplifiers (RF output: 6W min.).

As one of the world's leading suppliers of satellite transponders, NEC has contributed to a number of international programs, supplying hundreds of advanced transponders for INTELSAT-IV, IV-A and VI series of communications satellites.

NEC has also integrated and supplied all the transponders for Japan's communications satellites, including the world's first two Ka-band satellites, and various TT&C (tracking, telemetry and command) transponders.

Additionally, NEC was awarded a contract to develop and integrate high reliability transponders for BS-3a and -3b, Japan's next generation of direct broadcasting satellites.

ALL-SOLID-STATE UHF TV TRANSMITTERS.

The latest 30kW UHF TV transmitter from NEC sets a new standard for high output power in all-solid-state design.

The 30kW transmitter incorporates many enhancements including high-performance exciters, powerful transistor power amplifiers, low-loss RF combiners and high-efficiency switching regulators.

The 1.2kW transistor power amplifier, utilizing reliable, high-power and high-gain (120W typical and 7dB min. at 860MHz) bipolar transistors which were developed in-house, features a remarkably reduced component count—only 1.7 times larger than the conventional 300W PA.

Compared to tube types, the new transmitter features greatly enhanced economy and reliability. Safety and maintainability are also improved, while power consumption is reduced by approximately half.

NEC's new all-solid-state UHF TV transmitter series includes 15kW, 10kW, 5kW and 3kW models. A 30kW system is already in satisfactory operation.

NEC

made headlines for Cetus last year when the National Cancer Institute reported it was used in a promising clinical trial). They also include several drugs based on monoclonal antibodies (proteins selectively drawn to certain organic substances—in these cases, specific cancer cells).

"Strategically, selling generics makes a lot of sense," says Teena Lerner, a biotechnology analyst for L. F. Rothschild Unterberg Towbin (New York). "For one thing, it lets Cetus start training its sales force right away"—a process that could take some time, given the complex nature of cancer treatments. For another, it will give the company a broad line of cancer drugs, allowing it to sell an array of combination treatments, which appear to be particularly effective in cancer therapy. For reasons researchers don't fully understand, most cancer drugs are seldom 100% effective by themselves, but "can really mop up in combination; it's a case where one plus one equals five," says Lerner. "This seems to be especially true for the immune regulators, both in combination with each other and with conventional cancer drugs." The company could even manufacture premixed "cocktails" consisting of proprietary Cetus drugs and the specific generics found to work most effectively with them, a capability that competitors such as Genentech and Immunex don't yet have.

A share of the estimated $150 million annual market for generic chemotheraphy drugs should also generate a welcome stream of revenues over the "four to five years before Cetus's patented drugs are bringing in significant revenues," says John Girton, a securities analyst for Birr Willson & Co. (San Francisco). In light of 1985 revenues of only $46 million, he notes, these sales "give the company a quick start" toward recouping the staggering $30–50 million Cetus estimates it will spend to shepherd each of seven current proprietary drugs through the regulatory process.

The payoff had better not take too long, warns L. F. Rothschild's Lerner. "Selling generics may become much more competitive," she says, with possible price-cutting all but eliminating profits. Meanwhile, more fundamental questions abound as to how successfully genetic engineering patents can be defended from similar claims by competitors and from ingenious counterdesigns by pharmaceutical industry heavyweights. Cetus is betting it will be weighty itself by then and broad-based enough technically to weather such a storm if it must.—*Sarah Glazer*


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FACTORY AUTOMATION RECONSIDERED

A few years ago, the "factory of the future"—with robots and other automated machinery effortlessly turning out products from A to Z—seemed to be just around the corner. Today we know better. Flexible manufacturing systems, which are flexible only within limits, are now being installed more thoughtfully, one step at a time. The robot has traded its headliner status for a strong supporting role. And factory communications standards like General Motors' MAP, essential for smooth operation, are finally emerging.

FLEXIBLE MANUFACTURING SYSTEMS

Curing the cure-all

by Jeffrey Zygmont

Formerly hailed as a panacea for the ills of American industry—and prescribed in heavy doses—flexible manufacturing is now being scaled down. Because highly sophisticated systems are expensive and often incompatible with a company's other manufacturing operations, users of flexible automation have begun taking a step-by-step approach, starting with basic building blocks that can eventually be linked into larger systems.

This new conservatism is a backlash against the rapid push for sophisticated automation in the 1970s and early 1980s. Squeezed between maturing markets and low-priced foreign competition, basic metal-goods producers like automobile, machinery, and farm equipment companies eagerly embraced flexible automation to improve efficiency and cut costs. But a combination of poor planning, neglect of basic shop-floor management, and unrealistic expectations scotched many of these efforts.

Now, some manufacturers like Deere & Co. (Moline, Ill.) are taking a more critical look at their automation programs. No longer trying to buy its way out of plant-floor inefficiencies, Deere is attacking fundamental problems first—like cutting the time workers spend changing machine setups before running different parts, says vice-president James Lardner. The goal of such relatively modest efforts is to set the stage for advanced automation, like flexible manufacturing.

Replacing stand-alone machine tools used in batch processing, a flexible manufacturing system (FMS) is an automated system that machines a variety of metal parts in any order, as determined by product demand. It eliminates manual setup altogether, and instead uses a central control computer to direct each machine tool in the system. In effect, the controller electronically sets up each station for the particular part routed to it. Since a typical FMS integrates an average of eight machine tools and an automated material-handling system (plus accessories like an automated part washer and a coordinate measuring device for quality checks), the control computer can route parts sequentially through appropriate stations until the parts are completed, eliminating the need to queue work in process. Also, the computer coordinates routing of material and machine setup so that the system can make parts in

MIKE ABRAMSON

At Ingersoll Milling Machine, a technician oversees a five-machine FMS that makes custom components sized under a cubic meter.

random order, and in lot sizes as small as one item. And because of its flexibility, an FMS permits rapid product changes in response to market swings.

Since FMS originated as a metalworking concept, machine tool companies are the primary suppliers. Leading vendors in the United States are Cross & Trecker, White Consolidated Industries (Belvidere, Ill.), Cincinnati Milacron (Cincinnati), Giddings & Lewis (Fond du Lac, Wis.), and Ingersoll Milling Machine (Rockford, Ill.). Suppliers of industrial controls—like IBM's Manufacturing Systems Products Group (Boca Raton, Fla.) and General Electric's Industrial Systems Division (Charlottesville, Va.)—also put together flexible systems.

Unfortunately, many customers report a wide gulf between the performance and the promises of FMS. For instance, debugging a system used by the Electro-Optical and Data Systems Group of Hughes Aircraft (now owned by General Motors) took about three years, and the FMS is still less flexible than originally planned, reports Walter Lifsey, manager of fabrication for the division. One problem, he explains, is that the precision requirements of the metal parts—optical subassemblies for laser sights on tank guns—are higher than the system can deliver. Variances between the system's nine Kearney & Trecker machining centers exceed the allowable tolerances of many of the parts, he says. Thus parts often have to be manually positioned in a machine, and then manually checked for accuracy when an operation is complete.

Also, many of the parts must be made with specialized cutting heads that cannot be used on other parts. So although each station has a magazine that holds 68 different cutting heads for automatic loading onto the machine tool's spindle, an individual station can be set up to handle only two or three of the 16 separate parts for which the FMS was originally intended. "A particular part must go to a particular machine," thus limiting flexibility, says Lifsey.

Similarly, Deere & Co. is disappointed by the limited degree of random flexibility of a $20 million FMS installed seven years ago at its Waterloo, Ia., plant to make eight types of transmission and clutch housings for tractors. Lardner says the control sequence for totally random part sequences is too

complex for the system's software to handle. However, he blames this problem on Deere's failure to design simpler parts that have more common features.

"The FMS was a retrofit to a design problem that shouldn't have existed in the first place," says Lardner. Now the tractor maker recognizes that despite the sophistication of automation, product designers and manufacturing engineers must work together to assure easier manufacturability. "We can cut capital investment for automation by 50–60% just by getting the design and manufacturing people together from the beginning," he says.

Such costly errors in planning happened when manufacturers mistakenly assumed that flexible automation offered limitless flexibility. F. L. Caldwell, managing director of the manufacturing consultants Ingersoll Engineers (Rockford, Ill.), tells of a client who planned to buy an FMS before identifying what parts would be made on it. "They believed that since the system was a very flexible one, they'd be able to make anything they wanted on it," he says. But just because a system is flexible, "you can't build any size part out of any material; you have to put some constraints on it."

Yet tempering expectations does not mean abandoning FMS. On the contrary, the concept of flexible manufacturing continues to grow, and is expanding outside its original confines of metal machining; it is now gaining favor in assembly operations such as IBM's Charlotte, N.C., printer facility and its Lexington, Ky., keyboard factory. Flexible processing is even being implemented by chemical and pharmaceutical companies—though the companies remain secretive about their operations to protect the competitive advantages they plan to reap.

Nevertheless, "people are realizing that you can't make one product, then have a changeover and make an altogether different product," as in conventional batch processing, says William Weil, executive vice-president of the Center for Integrated Manufacturing, industrial consultants in Santa Barbara, Cal.

Current implementations of flexible systems emphasize careful, incremental planning, often starting with small-scale flexible manufacturing cells that can later be connected. "We look at it as a logical sequence of events," explains Ingersoll's Caldwell. It begins with general, inexpensive housecleaning on the factory floor—obvious (though often overlooked) measures like moving sequential work areas closer together. The next step is applying some smaller-scale automation such as an automated cell: perhaps a computer-controlled machining center, and a robot to load and unload parts. By starting slowly, Caldwell says, capital investment is spread out over a longer period; by contrast, a full FMS costs $10–25 million. What's more, shop management acquires the experience needed for operating the more complex, full FMS.

Machine tool makers themselves are emphasizing such an approach. "We're pulling back from large flexible manufacturing systems to favor more of a cell concept, where we can break it up into smaller parts, simplifying the system," says Eden Diver, vice-president and general manager of domestic metal-cutting operations for The Cross Co., a subsidiary of Cross & Trecker. By installing flexible automation step by step, he says, the customers "can get used to all the elements."

Many current FMS programs start small, with flexible cells that can later be linked together.

In addition to factory-floor support, other departments also "have to be educated to use FMS technology effectively," says consultant Weil. He cites the example of an electronics manufacturer using flexible automation to assemble printed circuit boards, where different batches of identical components varied so much in size that automatic parts feeders could not handle them. The company discovered that its purchasing department was buying the components from several vendors that supplied identical parts in slightly different sized packages.

Some of the more sophisticated users are already convinced. Deere, for instance, is identifying families of parts that have similar characteristics—although they may have vastly dissimilar uses. When parts are close enough in size, shape, and configuration to be machined at a single station, Deere dedicates a cell to that family. Because the parts are so similar, setup time is drastically reduced, eliminating the need for batch processing. One such cell, making 15 different medium-size gearcase and housing covers, retains a human operator, making it "an imitation of a flexible machining system without the high level of electronic sophistication," says Lardner. "We can make a much lower level of investment and get 70–80% of the cost advantage" of a full FMS, he claims.

Similarly, Rexnord, a Milwaukee producer of industrial drive chains, working with the industrial computer company Cimlink (Elk Grove Village, Ill.), married a robot and a metal-cutting lathe into a flexible cell for making the pins that bind the links of the drive chains. But first the company had to streamline its product variety, reducing its catalog of about 400 pins to seven families, each permitting alterations to satisfy unique customer needs. Rexnord also reduced its inventory of raw materials from about 50 to four different sizes of metal bars.

Of course, such bite-size chunks are still only islands of automation; they are not efficiently integrated into a large-scale manufacturing network. Therefore, explains consultant Weil, it is important to design cells with "hooks" that will later link them into larger systems. This means providing communication interfaces in the cell control computer and configuring the machines so that automatic material-handling systems can be added later.

While many companies take this building-block approach, some manufacturers operating successful FMSs are forging ahead with large-scale systems. After implementing an FMS that began in July 1984 to make parts for the B-1B bomber, Vought Aero Products Division of LTV Aerospace and Defense (Dallas) is "flexing" its system to make commercial aircraft components. That means adding a repertoire of about 800 parts to the 568 that were made for the bomber, says Arthur Roch, Vought's director of industrial modernization. Supplied by Cincinnati Milacron, the system features eight milling machines, each with a staging area where the next part waits to be loaded into a machine. This staging reduces idle time, since each machine cuts parts 80% of the time, compared with only about 15% utilization in conventional machining operations, says Roch.

He credits much of the system's success to the close working relationship between Vought and Milacron. "When you push technology as far as we are pushing it, you're really entering into a partnership with your vendor," he says. For instance, when Milacron was having difficulty developing software for the system, Vought sent six of its programmers to Cincinnati to help. As an added benefit, this gave Vought a cadre of experienced engineers to maintain the FMS and to develop future systems. "We have ambitious plans for automat-

WILLIAM FRANK MCMAHON

DAVID BUFFINGTON

Top: Deere's James Lardner is seeking less expensive ways than FMS to cut factory costs. Bottom: Arthur Roch runs more than 1000 different parts on Vought's FMS.

ing significant parts of our factories," Roch says.

Even when implementing a cell, such user/vendor teamwork is critical, reports Thomas Webber, general machining and fabrication superintendent at Martin Marietta's Y-12 plant in Oak Ridge, Tenn. After ordering a two-lathe, one-robot cell, plant personnel visited Cincinnati Milacron monthly, bringing the part-alignment and fire-prevention expertise needed for making their product—a family of uranium hemispherical parts of varying diameters for nuclear weapons. Thanks partly to the joint effort, says Webber, the cell is a success, reducing inventory and performing the work of five stand-alone machine tools. What's more, the cost and environmental impact of handling contaminated coolant and oil is lower, since the single cell uses less fluid than the stations it replaces.

Like Vought, Marietta considers the cell a springboard to future automation projects, notably a precision FMS by about 1990.

Development of such precise flexible systems is under way. Sensors are being developed to monitor the condition of cutting tools, enabling the control computer to compensate for cutting-surface wear, explains Cross's Diver. Key research focuses on vibration and acoustic sensors, as well as cutting-spindle torque monitors. Also, contact sensors must be refined for more precise automatic alignment of workpieces in machines. A precision FMS also requires in-process gauging of workpieces, rather than inspection of finished goods only. Machine tool makers are developing robots with surface-sensing probes for this task, reports Frost & Sullivan (New York) in an FMS study published last December.

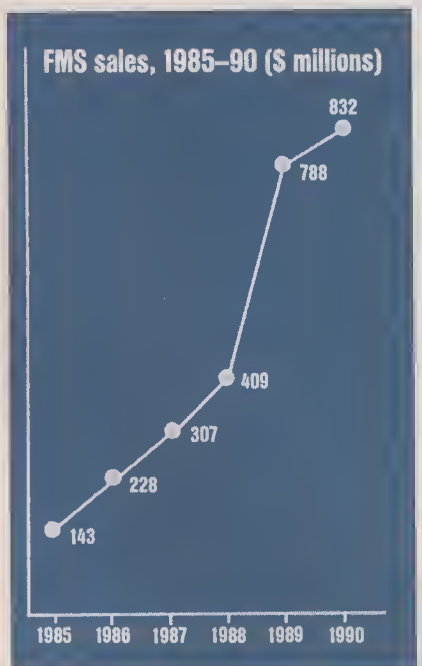
Software development is also being pushed, says Richard Kegg, manager of the Manufacturing Systems Division of Cincinnati Milacron. He says that research is emphasizing artificial intelligence systems that will solve some of the complex part-routing problems that still handicap many flexible systems. Expert systems, says Kegg, are needed to juggle the many variables involved in scheduling and material routing.

BUSINESS OUTLOOK

Flexible manufacturing systems begin to take hold

A total of 50 full-scale flexible manufacturing systems (FMS) were running in the U.S. in 1985. FMS vendors earned $143 million last year, based on the 12 new units sold and revenues derived from customer services, according to The Yankee Group (Boston), a market research firm. By 1990, 284 systems should be in place and revenues should reach $832 million.

Market leaders in the U.S. include such machine tool builders as Kearney & Trecker, a division of Cross & Trecker (Bloomfield Hills, Mich.), which claims 28% of the market; Cincinnati Milacron (Cincinnati), with 23%; Giddings & Lewis (Fond du Lac, Wis.), with 14%; and the White Sundstrand division of White Consolidated Industries (Belvidere, Ill.), with 11%. Major foreign competitors in the United States include Italy's Comau, and Mazak and Shin Nippon Koki of Japan. Most users in the U.S. are in the automotive, aerospace, and construction equipment sectors, including such firms as John Deere, General Electric, Boeing, and Westinghouse.



SOURCE: YANKEE GROUP (BOSTON, MASS.)

Flexible systems enable manufacturers to utilize their machinery more efficiently and reduce direct labor costs, while lowering lead times by an average of 40% in response to market demands and engineering changes, according to *A Competitive Assessment of the U.S. FMS Industry*, a report from the U.S. Department of Commerce. It is easier and quicker to reprogram an FMS unit to turn out different parts than to buy a new set of standalone machines or to reconfigure high-volume production lines for each new part.

The batch runs for which FMS is most suitable constitute about 35% of total U.S. manufacturing production, but it has only begun to penetrate this large potential market. Users have had to spend an average of $12.5 million in recent years to get a flexible system up and running; installation has generally taken 18–24 months, during which time no return is generated, according to Susan McGarry, executive director of research at The Yankee Group. "Most companies are not willing to pay the price of a full-blown FMS to get that level of increased manufacturing flexibility," says McGarry. Moreover, she points out, "many factories in this country don't even have numerically controlled machine tools yet, and are thus not ready to jump to the level of automation represented by FMS."

> ***"FMS has appeared at just the right time for U.S. manufacturing companies beset by an aging population of machine tools, high labor rates, and too much capital tied up in work-in-process inventory."***
>
> ***Alice Greene, Consultant***
> ***Engineering Automation Group***
> ***Arthur D. Little***

Vendors are responding to this situation by offering scaled-down versions of FMS known as flexible manufacturing cells. Such cells, consisting of a few machine tools, some automated material-handling equipment, and a small computer, are less expensive than FMS and offer a lower risk to companies learning to automate their production lines. In addition, the availability and affordability of more limited types of FMS are opening the market to firms that are smaller than the very large corporations that form most of today's FMS customer base. In 1985, a total of 250 cells were installed in the U.S., according to The Yankee Group. One hundred new cells were sold that year, and vendor revenues were $300 million. By 1990, over 1900 cells will be in operation, and cell revenues should be $1 billion.

Expansion of the FMS market is also aided by the customer-support services provided by suppliers. "FMS vendors are particularly interested in helping customers anticipate their automation needs, even if they are only buying a limited range of automated machinery now," says Alice Greene, a consultant with the Engineering Automation Group at Arthur D. Little, a consulting firm in Cambridge, Mass. As part of this process, vendors are designing systems that can be reconfigured to take advantage of expanded or new parts-production opportunities in the future. Thus, some of the companies that begin at more basic levels of automation should find it more feasible to adopt FMS down the road.

Expanded use of flexible manufacturing also depends on greater user sophistication in evaluating its benefits. Companies should not measure productivity only by how fast individual machines turn out certain parts, says Lee Morris, president of Robert E. Morris (Farmington, Conn.), the largest machine tool distributor in the U.S. That kind of assessment, he feels, ignores or underestimates factorywide costs that may be incurred in production bottlenecks, unnecessary inventory stockpiles, high defect rates and an inability to efficiently balance production with demand. "Although flexible equipment can be expensive," he says, "it can avoid the waste involved in many of these areas and thus help a company become more competitive." ***—John Krouse***

BILL BALLENBERG

FACTORY *Automation*

Top: Thanks to assembly robots, IBM's flexible system at Lexington, Ky., makes both keyboards and printers. Bottom: Hughes's Walter Lifsey says FMS is too inaccurate for high-precision machining.

Currently, control programs shuttle material through systems to minimize tool changes. However, factors such as the priority of parts must also be considered, explains Kegg.

Machine tool makers remain optimistic about the future of FMS—"it's the only solution to the problem of inventory," says Cross & Trecker's president, Richard T. Lindgren. Nevertheless, many admit that some customers have been disappointed. "When you set up a new facility, there are always teething problems, and the more you're pushing the technology, the more likely they become," says Lindgren. "That's the price you pay for progress."

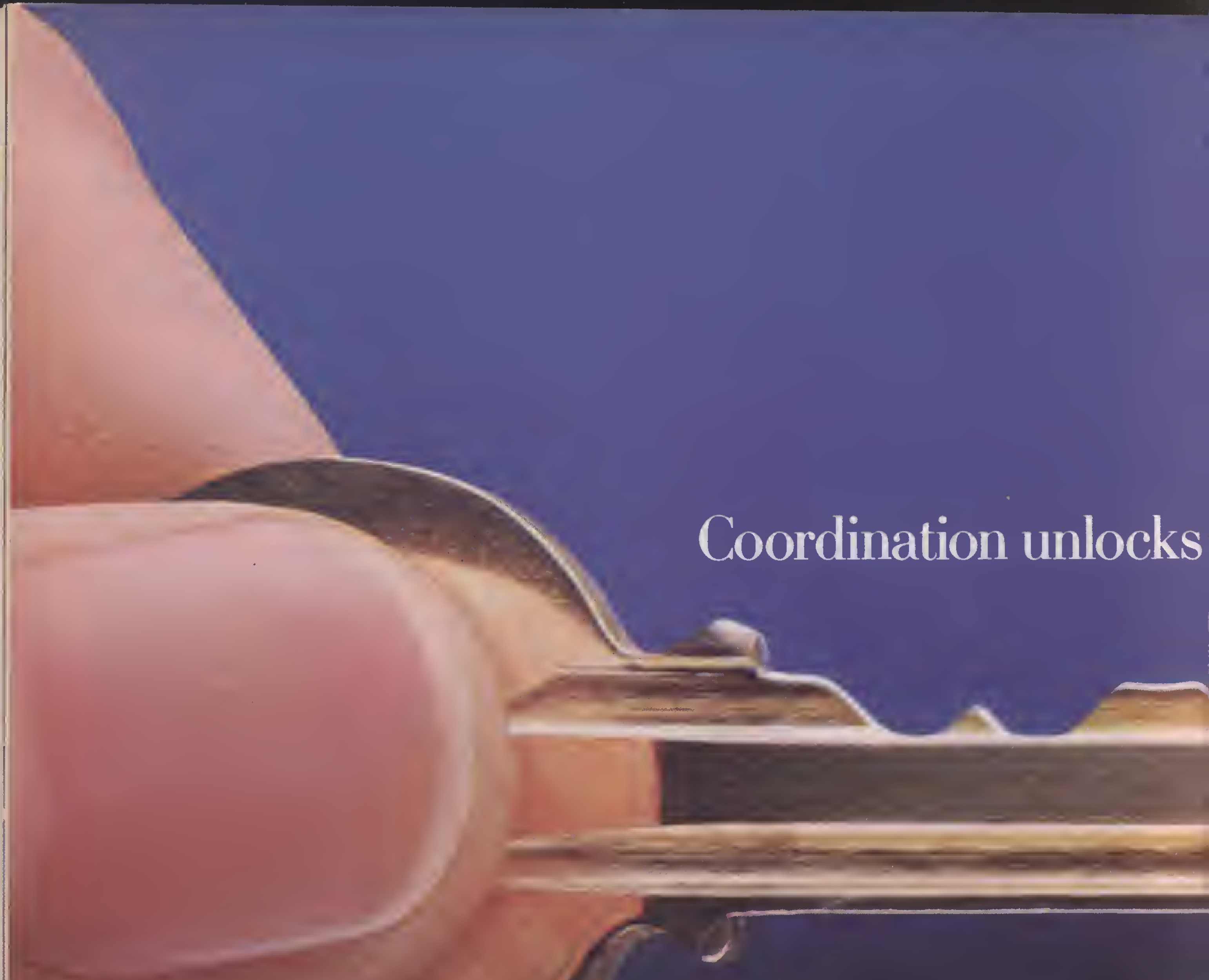
Recognizing that manufacturers aren't willing to pay *too* high a price, automation vendors are quick to point out that FMS is not the panacea it was once held to be. Rather than going for all-out flexibility, says Diver, Cross is pushing "appropriate flexibility." For a German automaker buying a machining line for four-cylinder engines from Cross, appropriate flexibility means the option to add an inch to engine-block height if future markets demand larger engines. Otherwise, the new line is a conventional fixed system.

Fixed (nonflexible) automation will remain an important aspect of future manufacturing, says Lindgren. However, he says, even such dedicated lines—when combined with an appropriate combination of manufacturing cells and FMSs in a single plant—will eventually provide flexible production; computer-integrated manufacturing will tie together "islands of automation" under a single, coordinating computer that can efficiently handle product variations.

But even as flexibile automation expands and improves, manufacturers will remain cautious. "Flexibility is a good word," says Deere's Lardner, "but you need to be precise about how much flexibility you're looking for. Infinite flexibility gives you infinite cost." □

Jeffrey Zygmont is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*



THE ROBOT
Just another machine?

by Herb Brody

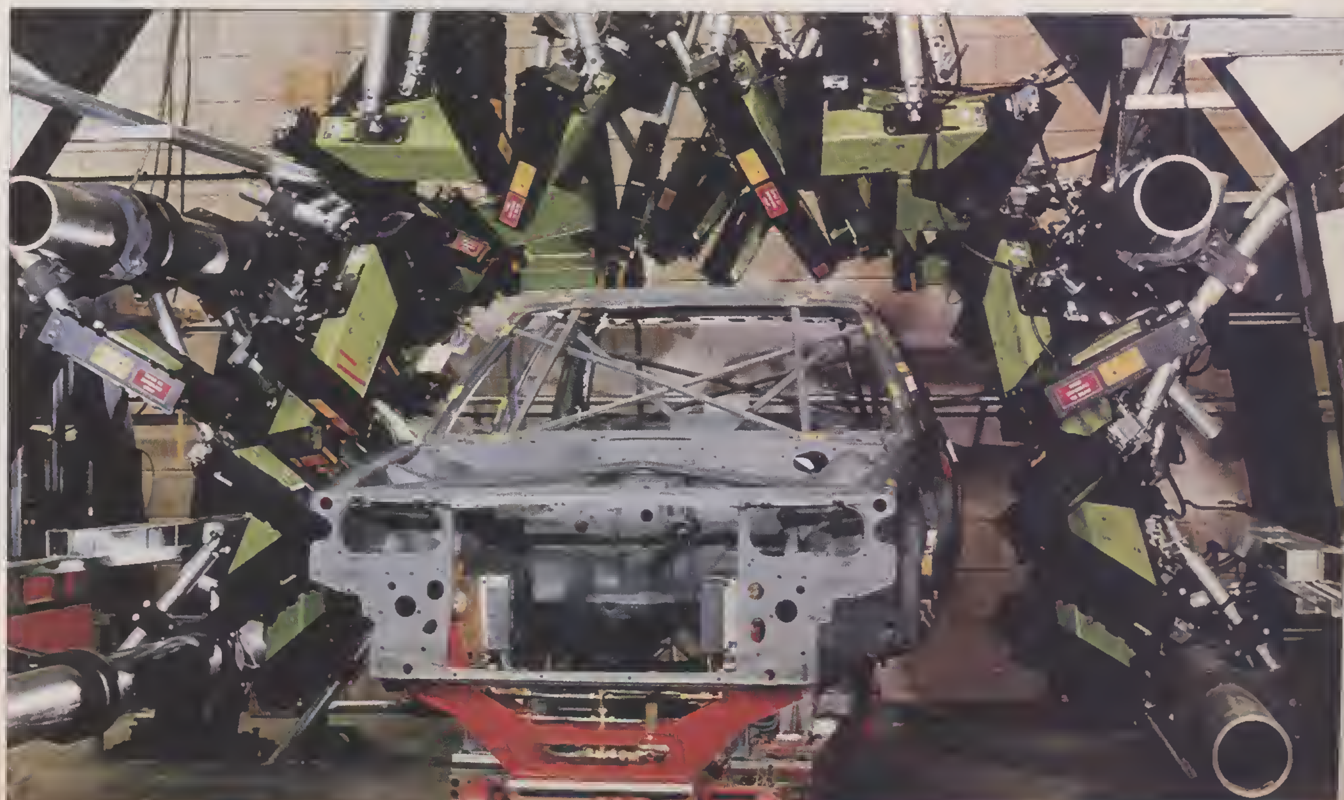
Only five years ago, the robot was being widely hailed as the rising star of factory automation. Manufacturers pinned their hopes on these vaguely humanoid machines to cut, drill, weld, paint, and fasten their way past the ascendant Japanese—who, it was noted, had taken an alarming lead in the robot race. Venture capitalists, convinced they were grabbing onto the next megatrend, poured investment funds into companies that made—or promised to make—robots.

Now that the dust is settling, it's apparent that robots may not be quite the pivotal technology that they were once deemed. "The robot is only a symbol," asserts MIT mechanical engineering professor and automation specialist Warren Seering. "It's just one of many computer-controlled machines on the factory floor." Indeed, much of the robot population (which now numbers about 20,000 in the U.S., according to the Robotic Industries Association) simply serves up parts and materials for other equipment—such as numerically conrolled machine tools—to work on.

Ironically, manufacturers have made relatively little use of the feature that distinguishes robots from conventional fixed automation: the ability to reprogram their movements. "We once envisioned using the same robot to install spark plugs one hour and paint cars the next," says Richard Beecher, robotics director at the General Motors technical center (Warren, Mich.). Reprogrammability also implied that a single production line could turn out a mix of different products, or at least different variations on a single product. Instead, robots have evolved into fairly specialized tools. They are generally bolted to the floor and fitted with a one-purpose hand. Not only do robots stick to a single function—say, welding—they also generally follow the same pattern of motion day after day.

In the auto industry, robots are typically reprogrammed only once a year, coinciding with new model introductions. One impediment to flexibility is that today's robots must be "taught" their motions while in place on the production line. Typically, an operator grabs the wrist and moves it through the desired path; a computer records the motion, and then plays it back at the appropriate time. Changing the program means interrupting production for another teaching session.

A Rover is inspected with lasers before robots install the windshield at Austin's plant in Cowley, England.



Increasingly, however, robots can be programmed away from the shop floor. Instructions can be coded into a computer language and typed into a terminal. Better yet is simulation software that writes the program for you, based on the on-screen manipulation of a graphical robot arm (HIGH TECHNOLOGY, Sept. 1986, p. 61).

During production, the program is downloaded into the robot as needed. A typical example is the robots that insert electronic components into printed circuit boards. In many cases, a company wants to make a mix of boards in small batches of varying size, depending on demand. A host computer is programmed with instructions on what parts to put where on each board type.

The main barrier to off-line programming—especially for larger and more complex motions than those required to stuff a circuit board—arises from robots' inability to move in exact accordance with a computer's instruction. Robots have evolved without particular attention to this shortcoming because of the prevalence of manual programming, where accuracy comes from the human teacher and the robot need only replicate the move precisely. While robot makers have honed repeatability to a few thousandths of an inch, they rarely specify their machines' initial accuracy.

One way to get around the robots' inaccuracy would be to program into each machine an "arm signature" that summarizes its imperfections—for example, if it routinely overshoots by 10% when moving to the right at a certain speed. Such a robot would then correct for its built-in errors each time it followed a programmed instruction. Unimation (Danbury, Conn.) will begin offering robots with such inherent error correction later this year, according to Maurice Dunne, vice-president for product planning. These robots will hit their programmed positions to within a thousandth of an inch, says Dunne—a 50-fold improvement over the company's present robots.

A more fundamental way to compensate is to endow robots with sensors, such as machine vision or tactile feedback. A sighted robot can miss its target, see its error, and adjust its position accordingly. It's arguable that off-line programming, and its attendant inaccuracies, only becomes feasible when robots have some way of detecting their location relative to the object they're working on.

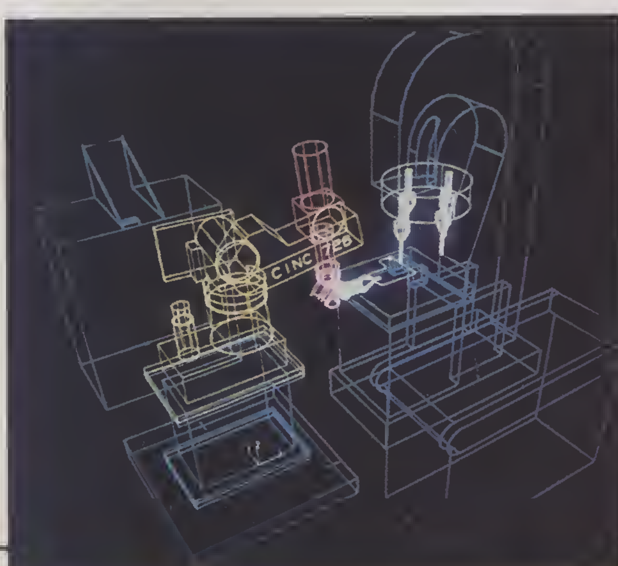
Sensors will go beyond improving a robot's accuracy. At least as significant will be their role in correcting for the inevitable variations in the manufacturing process. Parts don't always reach the robot in the same position or orientation; they may not even be the right parts. "Most of the things you could do with a sensorless robot have already been done," says Victor Scheinman, vice-president for advanced systems at Automatix (Billerica, Mass.), which makes sensor-based systems. Eric Mittelstadt, president of GMF Robotics (Troy, Mich.), echoes that thought. "In 1990," he asserts, "a robot that doesn't have vision will not be called a robot." (GMF, a joint venture of General Motors and Japan's Fanuc, is the world's largest maker of robots.)

One growing application for robots in the auto industry, for example, involves welding together metal plates using an electric arc. Arc welding demands that the torch trace the seam between plates to within a hundredth of an inch. Even if a robot had that kind of accuracy, the part-holding jigs and material-moving systems do not. It is thus essential that the robot watch what it is doing in order to stay on track. Unfortunately, an arc-welding bead glows with a brightness that blinds a video camera. General Electric (Orlando, Fla.) offers a tracking robot that avoids this problem by illuminating the seam with a laser and sensing the reflected beam with solid-state photodetectors; unlike a TV camera, these detectors remain functional even when subjected to the intense glare from the welding arc.

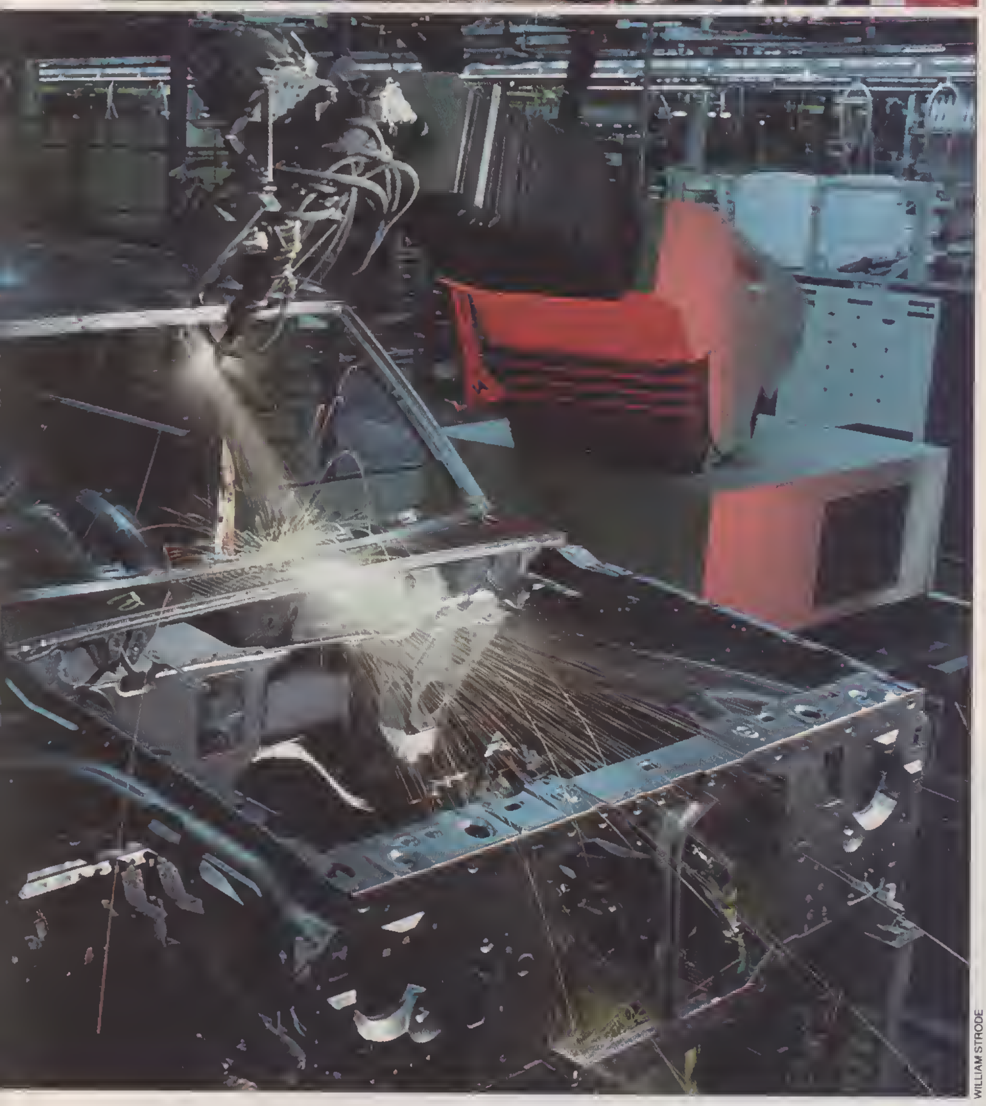
Such real-time guidance tends to slow the robot down, however, and is not yet widely used. In a more common class of applications, a vision system takes what amounts to a snapshot of the object the robot is to work on; knowing the object's position or orientation enables the robot to execute a preprogrammed series of motions, shifted according to the information from the vision computer. In electronics assembly, for example, vision systems are used to check the orientation of printed circuit boards; a robot then knows where to reach to insert the components.

Vision is also used to identify an object so that the robot knows which of several stored programs to call upon.

Ford Motor, for example, plans to use a robot to rivet parts onto truck chassis. Because of their many optional accessories, trucks are highly customized products; no two are exactly alike. Ford will



Graphic simulation allows robots to be programmed on screen, avoiding the need to interrupt production.



WILLIAM STRODE

The auto industry originally employed robots almost exclusively for welding (bottom). Now, the reprogrammable machines are being assigned a wider range of assembly jobs, such as installation of seats (top).

use a vision system to gaze at the truck, identify it by the pattern of mounting holes in the chassis, then direct a robot holding a rivet gun. The operation is expected to commence next spring, according to Walter Bohland, executive engineer at Ford's Robotics and Automation Applications Consulting Center (Dearborn, Mich.).

It's also possible to equip a robot with force sensors, so it can "feel" what it is doing. Many assembly operations require the insertion of a piece into a hole. A touch-sensitive robot can spiral around the target point, stopping frequently to attempt insertion. A large resistant force means it has missed the hole; a small resistance indicates proper insertion.

A more sophisticated way to use tactile sensing involves continuous monitoring of force, using the data to guide the robot. One application for this might be in grinding. As the grinding wheel moves across the part, any bumps will be felt as increased resistance. The robot will know to linger on those areas until the force diminishes, indicating that the lump has been worn down.

Although a robot that relies on sensor input will generally work more slowly than a nonsensing robot, the speed issue can cut both ways. A sighted robot that can swivel its wrist to pick up a part regardless of orientation eliminates the need to first fix the part in a predetermined position. Moreover, by detecting its own errors, a sensor-equipped robot can correct them on the spot, lessening the need for time-consuming inspection and repair farther downstream.

At IBM's recently automated plant in Lexington, Ky., for example, a robot lowers a typewriter assembly into a plastic housing and snaps it into place. The robot is equipped with a pressure-sensitive hand that feels whether the assembly pops back out. It's a simpler fix at that point than it would be farther down the production line.

The IBM plant shows one way to use robots in automated assembly. The work in progress is passed from robot to robot. A typewriter's frame and paper-feed structure, for example, are passed down a line of 56 simple robots, each of which does one simple job, such as inserting a screw. Such a system offers greater resilience than one in which a single robot performs a series of operations to assemble a complete item. "The more things a robot is asked to do, the likelier it is to fail," says Ray Reichenbach, IBM product manager for office typewriters. If one of the simple assem-

BUSINESS OUTLOOK

Robot industry looks to better days

After several years of rapid expansion, the robot market is currently in a period of slower growth. But long-term prospects for the industry still look favorable. Some 6400 industrial robots worth $500 million were sold in the U.S. in 1985, according to Tech Tran Consultants (Lake Geneva, Wis.); by 1995, annual sales should reach 165,000 units, constituting a $5.8 billion market. Four manufacturers were responsible for about 60% of all U.S. robot sales last year. GMF Robotics (Troy, Mich.), a joint venture of General Motors and Japan's Fanuc, dominates the field with 29% of the market, followed by Cincinnati Milacron (Cincinnati) with 13%, ASEA Robotics (New Berlin, Wis.) with 10%, and Unimation (Danbury, Conn.) with 9%. ASEA is a giant Swedish firm, and Unimation is a subsidiary of Westinghouse. Other significant players include American Cimflex (Pittsburgh), DeVilbiss (Toledo), Adept Technology (Sunnyvale, Cal.), and GCA (Aurora, Ill.).

The automotive industry uses at least 35% of all U.S.-made manufacturing robots, for tasks such as spot welding, spray painting, and machine loading. Other major end users include electronics and electrical equipment makers, foundries, and heavy equipment manufacturers.

"The industry is in a depressed state at present because its two biggest end users have had to cut back their capital spending plans," says Laura Conigliaro, a VP at Prudential-Bache Securities (New York). General Motors—the single largest U.S. customer for robots—has completed robot purchases for several large facilities and is carefully watching overall costs after spending heavily to acquire Hughes Aircraft and Electronic Data Services. Purchases of automated equipment by the electronics sector have also slowed in response to growth problems besetting that industry. As a result of such factors, Conigliaro estimates that robot sales will be flat over the next two years, and could even recede slightly, leading to a continued shakeout among marginal producers.

"The benefits of robots must be evaluated on a broader basis than direct replacement for human labor. They can bring improved quality, faster production, and more flexibility to factory operations."

Kevin Ostby
Director of Marketing
GMF Robotics

Industry growth rates, however, could eventually climb back to their former high levels. Tech Tran expects robot sales to grow at a 38% annual rate over the next 10 years, for a number of reasons. Auto industry spending should pick up again as new projects begin to come on line in 1988, says John D. Meyer, Tech Tran's president. Moreover, only 20,000 robots have been installed in the U.S. for all applications. "This is still a young industry whose penetration of manufacturing markets is relatively small. New or expanded arenas for applying robots should open as better accuracy and improved control techniques enhance robot capabilities and as the costs of robots come down," says Meyer.

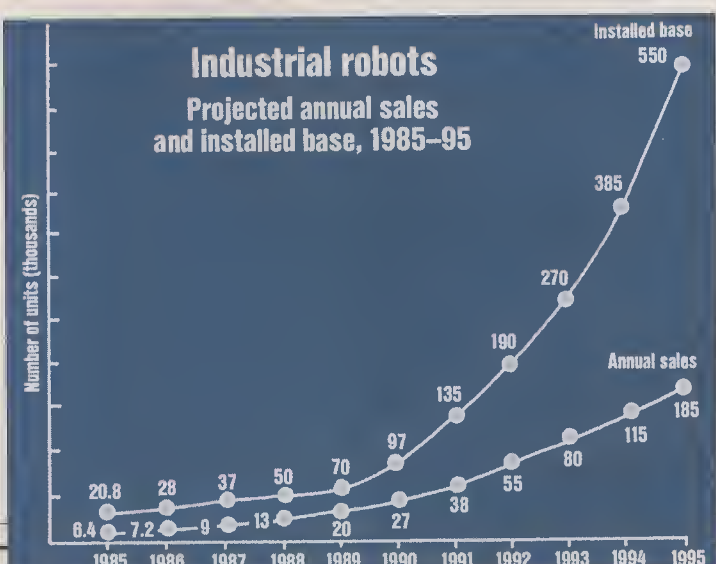
Assembly applications are currently the fastest-growing sector for robot use. About 24% of all U.S. robots are being used for material handling; almost the same proportion is devoted to spot welding and machine loading. By 1995 the largest application will be assembly, accounting for 30% of all the robots in use (compared with 5% at present), according to Tech Tran.

Two developments are making robots more attractive for assembly, says Bryan Carlisle, president of Adept Technology, a firm that specializes in this area. One is the use of vision systems that enable robots to pick parts out of general-purpose trays or conveyor belts; visionless robots would have to use custom-designed parts feeders that must be redesigned and installed for each new product. In addition, direct-drive robots, in which the output shaft is turned without gears, can carry out fine motions for tasks requiring small tolerances. At present, most robots are driven by gears; over time, gear wear reduces precision.

Robots are also expected to diffuse into a wider range of businesses over the next decade, making the industry less dependent on capital spending cycles in the automotive sector. For example, robots may find use in such nonmetal processing operations as tire manufacturing, glass loading and unloading, and asbestos processing. In addition, corporate giants will not provide the only homes for robots; even small machine shops can now make cost-effective use of such equipment.

Another impetus to robot use is the greater understanding customers are applying to automation plans, according to Kevin Ostby, director of marketing at GMF Robotics. "Customers now appreciate that people are an important element in any automation system," he says. "When employees are involved in purchasing decisions and training programs before equipment arrives on the factory floor, their commitment to making it work successfully goes up."

—Dennis Livingston



SOURCE: TECH TRAN CONSULTANTS (LAKE GENEVA, WIS.)

bly robots malfunctions, he adds, a person can easily fill in temporarily.

As IBM's typewriter operation illustrates, a robot is just a small cog in the successfully automated factory. Each robot repeats the same job time after time; the real star of the show is a sophisticated conveyor network that makes sure that work in progress stops only at those robot stations needed for its particular set of features. "A robot doesn't pay off if it simply replaces a person on the production line," says Reichenbach. Only when supported by technologies such as automated parts-handling systems do robots make economic sense.

Although robots are often touted for their flexibility, changing a robot's job is usually not easy. Reprogramming the arm motion is just the beginning, notes Reichenbach; modifications are also required in such ancillary equipment as end effectors (the tools that attach to the wrist) and the equipment that presents the parts to the robot. Ironically, the ability to shift to new products will come not from the robots but from a cadre of human workers that supplements the automated line. "No robot is ever going to be as flexible as a person," says Reichenbach.

The most avid practitioners of robotic assembly are unquestionably the Japanese. In one of the most impressive displays, a line of 47 no-frills robots churns out 100,000 quartz watches a month, at Seiko/Epson's Shimauchi plant in the mountains west of Tokyo (HIGH TECHNOLOGY, Sept. 1986, p. 22). As at the IBM plant, each robot performs one quick job and then passes the work to the next machine.

Not all processes are suited to this kind of robot assembly line, however. A good example of another approach is being developed by General Dynamics (Fort Worth, Tex.) for assembly of the F-16 aircraft. Building the plane requires drilling some 6000 holes and inserting a rivet or some other fastener into every hole. General Dynamics, considered the leading robot user in the aerospace industry, is planning to assign the entire job to a single robot station. The robot will move into position, drill a hole, gauge its depth, pick up and insert the proper fastener, and shave off the protruding end. This monotonous job is now done manually by workers who tend to lose their concentration and make mistakes, according to manufacturing systems manager Robert McMahon. Robots offer two main advantages over fixed automation, he says. One is cost: about $150,000, versus millions of dollars for a numerically controlled machine tool to cover the same volume of space. Also, unlike a machine tool, the robot can be easily retooled in the future to perform a different job, such as materials handling or deburring.

Like conventional automation, however, robots are often valuable not for their flexibility but for their predictability. In an assembly plant, the ability to know exactly how many units a robot will build in a given time dramatically reduces the number of extra parts that must be kept at the ready. The cost of managing this extra "just in case" inventory often exceeds that of making the product, says MIT's Seering.

A related benefit has sprung from the first job for which robots were extensively used, spot welding of automobiles. When the job was done manually, cars had to be designed with more weld points than they really needed, according to Lloyd R. Carrico, technical director of INFAC, an Indianapolis-based organization specializing in automation marketing and education. The extra welds were stipulated to make up for the ones that were frequently skipped by the person wielding the torch. Now that the automakers can count on the welds being made, car designs include only those that are necessary, thereby speeding production.

Robots are often valuable not for their flexibility but for their predictability.

Any machine as complex as a robot will fail from time to time, and robots have had at least their share of reliability problems. Chrysler Motors, for example, was "shocked" when none of 200 robots tested for installation in its Sterling Heights, Mich., assembly plant passed muster, says Robert J. Piccirilli, Jr., director of manufacturing engineering. Among the common problems: arms were too weak to hold the load, motors failed because of poor circuit design, and software bugs made the robot move unexpectedly when first turned on.

As a result of that dismal showing, Chrysler has instituted a stringent screening procedure to ensure that bad robots don't make it into the factory. First, the robot is made to operate continuously for 50 hours, exercising its joints in numerous possible combinations. After surviving this burn-in, the robot must operate automatically for 20 consecutive hours at its intended station on the line (as must all of Chrysler's production equipment); any stoppage sets the clock back to zero.

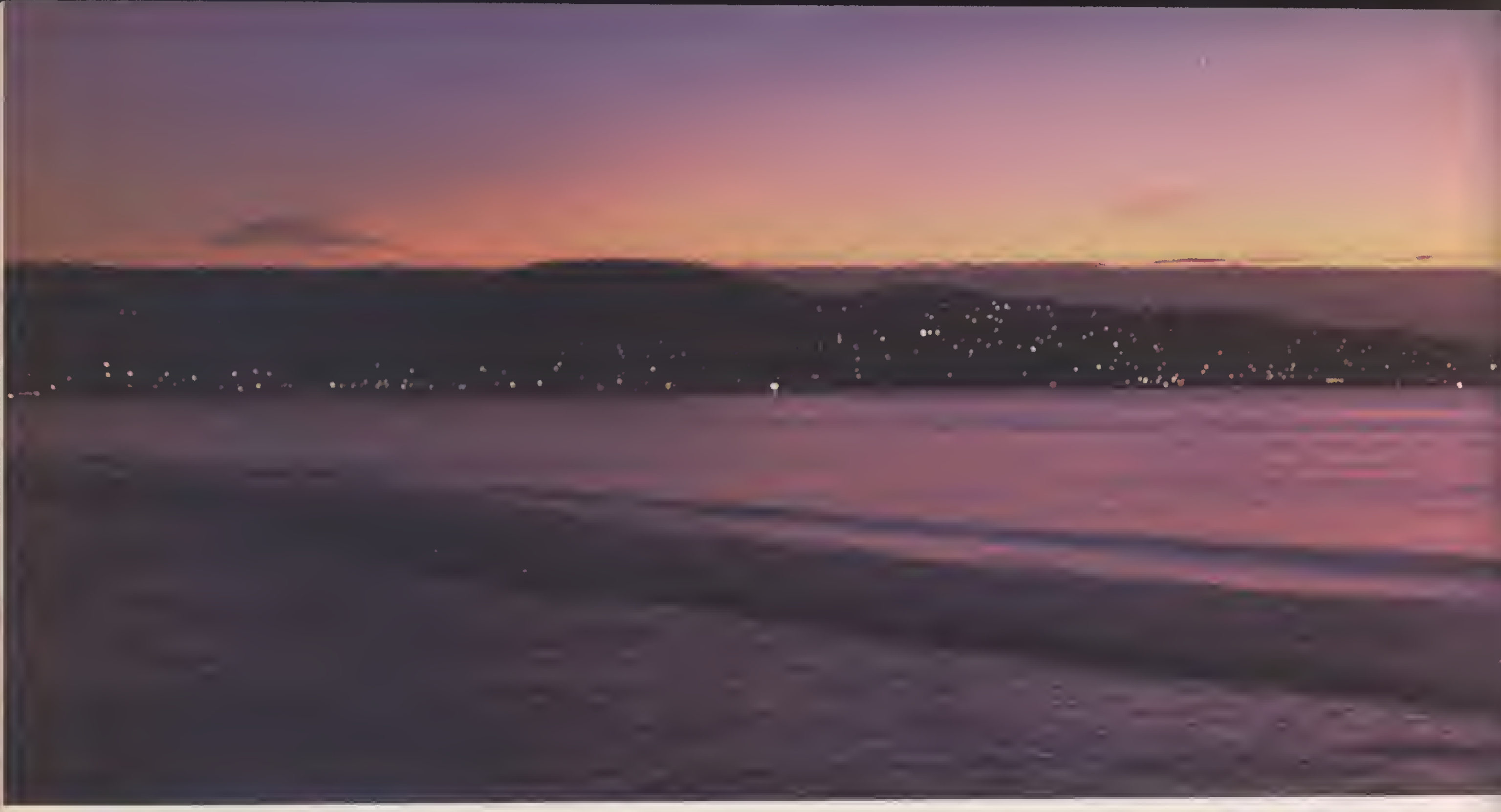
Even if they don't outright fail, robots often do not perform exactly as their maker claims. One problem is that the robot industry has not standardized the measurement of basic operational characteristics such as speed or repeatability—how closely the robot can duplicate a movement that it's been taught. To address this problem, the Industrial Technology Institute (ITI) in Ann Arbor, Mich., has begun testing robots according to strict rules, and supplying the data to the robot's maker or prospective user. "We're sort of the Underwriter's Laboratory for robotics," explains Robert B. Di Giovanni, spokesman for the institute's Robotics Evaluation Center. The availability of this independent test facility should relieve manufacturers from one of the more tedious and time-consuming tasks related to robot purchasing and installation. Ford Motor, for example, recently quit its robot test program, opting to rely on ITI's data.

The idea that robots need more careful checking than other machines bothers some users. "We shouldn't have to develop all kinds of debugging systems to make sure the robot works," complains Frank A. DiPietro, director of production engineering for GM's Chevrolet-Pontiac-Canada division, which uses more than 3000 robots. "We ought to be able to take that for granted."

Many manufacturers have assumed not only that the robot is going to work, of course, but that it will make them more productive. That's often not the case, though, contends MIT's Seering. Robots are slower and more expensive than people, he says, and are therefore justified only in special cases where a human would face a risk such as a safety or health hazard. In any case, says Seering, replacing factory-floor labor is only a small part of the automation story. "Blue-collar labor is cheap. What you really want is to achieve better order so that you can get rid of some of the white-collar people. They're the expensive ones." □

Herb Brody is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*



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GM'S AUTOMATION PROTOCOL

Helping machines communicate

by Jeffrey Bairstow

Look around any major factory built or modernized in the last decade and you will see a multitude of electronic devices made by a large number of vendors. Glance up and you will see a rat's nest of wiring that connects some, but rarely all, of this equipment. And if you could hear the electronic signals these units produce, it would be a din to make the Tower of Babel, by comparison, sound like a gentle breeze through the trees.

"The success of tomorrow's industrial plant will depend on its ability to gather, share, and utilize information for more productive planning and control," says J. Tracy O'Rourke, president of Allen-Bradley (Milwaukee, Wis.). But in the factory of today, communication is probably the single largest and most troublesome problem facing users and suppliers of factory automation systems. It is the need to standardize factory communications that has driven General Motors to devise its own solution—the Manufacturing Automation Protocol (MAP)—which the company's engineeers feel could eliminate the electronic Babel.

Having installed more than 40,000 programmable devices in its facilities, and facing the prospect of perhaps five times as many in the next five years, GM has considerable incentive to act. It first recognized the scale of the factory communications problem in 1980 when the company set up a task force to investigate local-area networks—networks for interconnecting computers, robots, and other electronic gear that must work together in a factory or an office.

The task force decided to base its work on an existing computer communications standard—the Open Systems Interconnection (OSI) reference model developed by the International Standards Organization. The OSI model is a generic seven-layer model of a communications system in which each layer performs different communications functions, from applications to physical connections. The same model has been adopted by the Corporation for Open Systems (Vienna, Va.) for computer communications (HIGH TECHNOLOGY, Sept. 1986, p. 30).

As a result of the work of the task force, the Manufacturing Engineering and Development Group of GM's Technical Center (Warren, Mich.) decided in 1982 to develop the set of OSI-based communications protocols now known as MAP. In 1984, GM started a five-step process to implement MAP in the company's plants. "By 1990, most computer and control equipment in GM plants will be on a MAP network," claims Michael Kaminski, manager of the MAP group at the GM Technical Center.

But just what is MAP and why is its adoption moving ahead so rapidly? In technical terms, MAP is a seven-layer, 10-megabit-per-second, broadband, token bus–based communications standard for factory applications (see diagram). Because it is concerned with communications rather than applications, it specifies how a robot might communicate with a computer over the network but not how the robot will respond to the computer's programs.

In broadband transmission, many signals can be transmitted over a network at the same time. To prevent data "collisions," a special bit pattern called a token is passed along the network. When one station receives the token, it may pass data to another station. The advantage of a token bus network is that the maximum time any station must wait before passing a message is precisely specified. This is vital for real-time systems, where actions must take place within a particular time.

Thus, with the MAP standard, a single broadband coaxial cable can link together many devices on a common network. "MAP could be the interstate highway for factory communications," says Glen Allmendinger, president of Harbor Research, a Boston-based automation consulting company. And not only can the cable carry control signals and plant data, but channels can be devoted to audio or video transmissions for internal communications—say, for retraining.

The MAP standard follows the OSI model in specifying how devices and application programs will communicate with each other. The top three layers (5 to 7) govern the interconnection of different networks. The other layers are concerned with the interoperability of devices connected to a network. To allow two different applications to communicate with a MAP-based network—as when files are transferred from a sales order system to the production scheduling system—requires all seven layers of MAP. But to permit two devices, such as a robot and a numerically controlled milling machine, to communicate might require only the first four layers.

Level 1, the physical layer, deals with most of the hardware questions involved in networking, such as the type of cable (75-ohm coaxial), the data transmission rate (10 megabits per second), and the network access method (token bus). At this level, two networks

ARNOLD ZANN

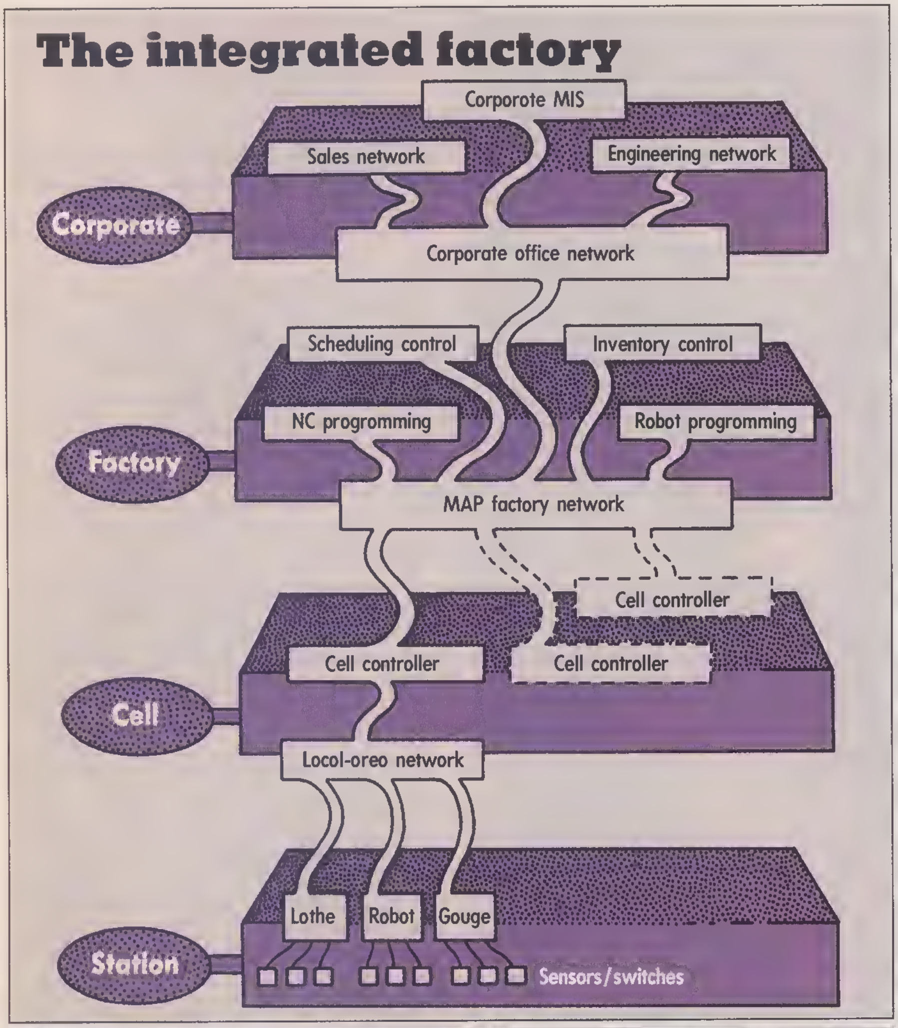
Allen-Bradley's Tracy O'Rourke: "The success of tomorrow's industrial plant will depend on its ability to gather, share, and utilize information."

might be connected using a repeater, a device that amplifies signals. The second MAP level, the data link layer, manages the communication linkage between two end systems. It is also responsible for error checking and the composition of the actual "frames" of data that are sent out on the network. Two associated devices—say, a lathe and a measuring system—might communicate at this level, provided they use the same frame size for data and have a common addressing scheme.

However, independent devices connected to the same network will most often require all of the lowest four layers of MAP for communications. Level 3, the network layer, establishes a route for communications between devices with different addressing schemes, and level four, the transport layer, actually manages communications between devices, ensuring that messages are transferred correctly. Using all four layers ensures "transparency," in that the connected devices need not have a common addressing scheme. Each device is capable of sending and receiving messages independently and will recognize messages intended for it.

The upper three layers largely govern the interconnection of networks. The fifth, or session layer, an extension of the transport layer, manages connections between pairs of programs running on different devices. The sixth level, the presentation layer, translates and formulates data when required, so that, for example, application programs will work correctly with any display terminal connected to the network. Finally, the application layer provides access to the network for application programs and data file transfers. For one application to communicate with another on a MAP-based network will require all seven layers of the protocol. All the layers are also needed to interconnect a MAP network with a different network such as an Ethernet, the local-area network developed by Xerox.

Several traditional factory automation equipment suppliers, such as Allen-Bradley, Gould, Honeywell, and Hewlett-Packard, have announced products that will conform to parts of the MAP standard. Semiconductor manufacturers Intel and Motorola are



DAN COLLINS

For the modern manufacturing plant, MAP could be the link between corporate networks and the factory floor, as well as the backbone tying together the manufacturing cells.

producing board-level interfaces to link existing equipment to MAP-based networks. They and other semiconductor makers are working on VLSI implementations of the interfaces to bring the cost of interconnection down. Several smaller companies, such as Charles River Data Systems (Framingham, Mass.), Concord Data Systems (Marlborough, Mass.), and Industrial Networking (Santa Clara, Cal.), are scrambling to develop network interfaces and software for what is anticipated to be a rapidly growing market.

Implementation of MAP networking is likely to be a lengthy, difficult, and costly process, even for a company with the resources of GM. Existing equipment will require additional network interfaces and operating software before it can be attached to a MAP-based network. According to GM's Kaminski, a five-step evolution is necessary, starting with the interconnection of currently incompatible computers (the step GM has already begun) and arriving at a full network capability by 1988. However, Kaminski acknowledges that further MAP development is needed for real-time communications between host computers and programmable devices on the factory floor. In essence, this work involves stripping the MAP communications down to its bare essentials so that programmable devices can handle the short, rapid messages required for process control. Thus a lower-level version of MAP, called mini-MAP, is under development using simpler single-channel baseband communications at 5 megabits per second.

Although GM and its Electronic Data Systems subsidiary probably have enough purchasing power by themselves to encourage vendors to build equipment to the MAP standard, the company decided that MAP should be an open, nonproprietary standard. Well aware that other large manufacturing companies were facing similar communications problems, GM joined forces with McDonnell Douglas to start a MAP Users Group, which met for the first time in March 1984. That initial meeting brought together some 60 people representing 36 companies. Now the meetings attract more than 500 people

ANDREW SACKS

GM's Michael Kaminski: "By 1990, most computer and control equipment in GM plants will be on a MAP network."

SETH RESNICK

Harbor Research's Glen Allmendinger: "MAP could be the interstate highway of factory communications."

representing 300 companies, both users and vendors of automation equipment. And MAP Users Groups have been formed in Canada, Europe, Australia, and Japan.

At the Autofact trade show in November 1985, GM and Boeing sponsored a working demonstration of a computer-integrated mini-factory based on a MAP network using hardware and software from more than 20 different vendors, including Allen-Bradley, DEC, Honeywell, IBM, Motorola, and Siemens. GM is installing a plantwide MAP network in its Saginaw (Mich.) Steering Gear Division's "factory of the future," scheduled to be completed in the fall of 1987. Other large companies, notably Eastman Kodak (Rochester, N.Y.) and John Deere (Moline, Ill.) are also committed to major MAP installations.

But while some see MAP as a complete solution to the factory communications problem, others suggest that MAP's software requirements may be inordinately complex and its hardware too expensive. For example, the factory communications solution of Cimlinc (Elk Grove, Ill.), an automation equipment supplier, is based on using the Ethernet network for design and manufacturing engineering, tied to either a proprietary network or a MAP-based network for the factory floor. John West, Cimlinc's president, points out that Ethernet is a well-established networking standard with protocols covering layers 1 through 5 of the OSI model. Because these protocols, designated TCP/IP (for "transport control protocol and internet protocol"), were developed for the Defense Department's Arpanet computer network, the associated technology is well understood and software is readily available to handle these protocols for a variety of computers.

Ethernet is particularly attractive for office automation and for design and engineering applications because it was created to handle large text files in situations without the real-time demands of factory control. Also, Ethernet is a single-channel baseband network, which is simpler to implement than the complex multichannel broadband transmission of MAP. A typical MAP interface requires a token bus controller to handle the passing of the control token, a broadband modem to transmit and receive data on the appropriate channels, and a broadband interface controller to manipulate data and control the modem. These devices are inherently more expensive than the equivalent Ethernet interface.

"Some 400 vendors are committed to making MAP-compatible products."

In addition, Ethernet uses a simpler technique to prevent data conflicts. Devices are attached to a coaxial cable, as in a MAP network, but the procedure for sending data is different. A device waits until no signal appears to be present on the cable and then begins transmitting. If the device discovers that its transmission is colliding with another device's data, it stops, waits a random length of time, and then tries again.

This technique is known as carrier sense multiple access with collision detection (CSMA/CD). Because several attempts may be necessary for a successful transmission on a busy network, the actual length of time for a device to respond to a particular control signal cannot be accurately predicted. Ethernet is therefore not suited to situations that require short response times, as in chemical process control.

Many computer and automation equipment suppliers already have a large investment in Ethernet networks. For example, at a recent MAP Users Group meeting, Digital Equipment Corp. presented a strategy for continuing use of its proprietary DECnet protocols, which were derived from Ethernet. "Applications that need to communicate with foreign (non-DEC) systems will use MAP, while applications that wish to communicate with DEC systems will continue to use DECnet protocols for performance reasons," says Donald Bell Irving, computer-integrated manufacturing product manager for DEC. Thus DEC's engineers envision a coexistence with MAP rather than a wholesale adoption of the new protocols.

The situation is further complicated by the emergence of yet another networking standard, the Technical and Office Protocol (TOP), developed by Boeing Computer Services (BCS) in Seattle. TOP is also based on the seven-layer OSI model, but the physical link—the first layer—is an Ethernet type. Ethernet was chosen because a large base of networking equipment already exists and the CSMA/CD technique has proven to be capable of handling a wide range of business and engineering applications, from document interchange to graphics processing. Although layers 2–6 in TOP are the same as in MAP, the application layer, the seventh, has simpler and more limited file management protocols. These are oriented strongly toward office automation and more conventional data processing requirements. For example, the protocols cover message handling for electronic mail services, and job transfer and manipulation for remote batch processing.

Just as GM gives preference to suppliers who conform to the MAP standards, so Boeing does with TOP. But "TOP is not competing with MAP," says Laurie Bride, manager of advanced data communication technology for BCS. Indeed, Boeing participated in the automated factory demonstration at Autofact '85 with a TOP network linked to the main MAP manufacturing network. And Boeing has joined forces with GM in holding joint MAP and TOP Users Group meetings. Thus, as with DECnet and other proprietary Ethernet-based protocols, TOP appears likely to coexist with MAP in an integrated engineering and factory automation system.

Indeed, for companies with a stable product line, such as Boeing Aircraft, the extreme flexibility of MAP may not be necessary, because assembly lines are revamped infrequently and the rate of product change is slow compared with that of an automobile maker. Another major defense contractor, Northrop, intends to use the Arpanet TCP/IP protocols in favor of MAP, largely because the software for those protocols is available today for IBM computers, of which Northrop is a major user. Where MAP is expected to make headway is in industries with a high degree of product change, such as automobiles and packaged consumer goods, says Harbor Research's Allmendinger. The additional costs for the broadband MAP network and for the extensive communications software will be recovered, he says, by reusing equipment as production lines are revamped for new-product manufacture.

"Installing MAP today will not close the door to future developments."

But manufacturers can reap similar benefits at less expense, says Allmendinger, by going with a supplier who offers an integrated set of proprietary networks that can communicate between the three basic levels of control requiring real-time operation: corporate systems (typified by today's management information systems), the plantwide manufacturing control and scheduling system, and the individual manufacturing cell or group of machines (see diagram, p. 40). "Allen-Bradley, for example, has both broadband and baseband networks and its own proprietary network for linking individual machines. Those networks will all play well together at a lower cost than a full-fledged MAP system."

The incentive to install MAP and other plant networks will clearly be driven by economics. Today the costs of MAP networks are high—around $5000 per connection, according to Margaret Merrick, manager of communications products for Foxboro Co. (Foxboro, Mass.). Proprietary networks, such as DECnet, can offer a much less expensive solution. But when MAP interfaces become available as very-large-scale integrated circuit devices (probably before the end of this decade), costs are expected to drop rapidly. "The Japanese, Korean, and Taiwanese electronics makers will begin making MAP interfaces and will drive the price down to less than $500 per connection," says Allmendinger. Manufacturers will then be able to offer MAP interfaces as part of a product rather than as separate devices. Thus, perhaps by 1990, MAP will be able to compete economically with Ethernet and proprietary networks.

However, in manufacturing industries, where planning perspectives often extend out for considerably more than five years, decisions on installing factory networks may need to be made today. A decision to install a less expensive proprietary network may be shortsighted, say some experts. "There's absolutely no question that MAP networks have tremendous potential in the factory," says Gary Bodnar, an associate with McKinsey & Co. (Cleveland, Ohio). "MAP will meet the challenge of enabling equipment from different vendors to communicate reliably. Sure, proprietary networks may be a near-term solution, but MAP is the way to go for a long-term, flexible answer to factory communications."

"Some 400 vendors are committed to making MAP-compatible products," notes Robert C. Harbage, a senior consultant with Arthur D. Little (Cambridge, Mass.). "There has been a slow start as vendors waited for the standards to settle down, but there will soon be a flood of compatible equipment." As more equipment arrives in the marketplace, costs will come down, making MAP networks more competitive with proprietary networks.

Most observers feel that MAP will not outdate itself—that it is sufficiently flexible to adapt to changing technology. "The MAP standards are progressing nicely," says Bodnar, "so manufacturers can take advantage of MAP today and be sure that they are not closing the door to future developments in a fast-moving business." Indeed, as manufacturing companies integrate their "islands of automation" with production control systems and engineering design, says ADI's Harbage, their communications demands will increase rapidly, requiring the flexibility and high capacity of a MAP network. □

Jeffrey Bairstow is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*

CD-ROM: MASS STORAGE FOR THE MASS MARKET

Current discs put vast databases at your fingertips. Coming soon: interactive and multimedia versions.

by Jeffrey Bairstow

The same 4.7-inch plastic disc that has revolutionized audio recording can now be used to store vast amounts of information for personal use. One "compact disc read-only memory" (CD-ROM) can hold 550 megabytes of data, the equivalent of 1500 floppy disks or more than 200,000 pages of text, enough for the *Encyclopaedia Britannica* or for complete SEC data on every company listed on the New York and American Stock Exchanges. About 10,000 CD-ROM drives will be sold this year, but nearly a million are expected to be in use by 1990, according to Link Resources (New York).

Already, for $1000 or less, a personal computer user can attach a CD-ROM drive and controller and install the software necessary to access CD-ROM versions of huge databases previously accessible only through on-line services such as Dialog or The Source. Using a CD-ROM, a personal computer owner can scan a database or shift information to a word-processing program or electronic spreadsheet without worrying about rapidly escalating fees for connection to an on-line service. The discs can be carried about easily or mailed with little chance of serious damage. The discs are replicated through the same techniques as audio compact discs, and software is available to prepare mainframe and PC databases for storage on a CD-ROM.

The main disadvantage of the CD-ROM is that currently available discs cannot be modified by the user. But industry experts are predicting that writable discs and drives will be commercially available in 1987. This type of disc, called CD-PROM (the *P* stands for *programmable*) or WORM ("write once, read many times"), cannot be erased after a user records data. Nonetheless, CD-PROMs are expected to be widely used, especially for archiving data such as bank and tax records and for backing up the more volatile forms of magnetic disk storage. Electronically erasable discs have been demonstrated in the laboratory by 3M (St. Paul, Minn.), Sony, and Hitachi, among others, but are not expected to appear commercially until 1990.

All the various forms of compact disc for computer storage are expected to comply with standards developed jointly by Philips and Sony. By virtue of their patents and dominance in the field, these two companies have been able to establish worldwide standards for digital audio recording on compact disc and the physical format of data for the CD-ROM.

Earlier this year, Philips and Sony jointly announced a third compact disc standard, called Compact Disc-Interactive (CD-I). This is a specific application of CD-ROM with rigidly defined implementations similar to the CD audio format. CD-I is expected to be a major consumer product, providing opportunities to create some startling multimedia programming—for instance, an

WILLIAM JAMES WARREN

Warner's Stan Cornyn predicts a major consumer market for programming in the new interactive format for compact discs.

interactive guided tour of London that can also move backward in history. Unlike CD-ROM, however, the CD-I player will not be a computer peripheral but a self-contained unit targeted largely at the mass market. Given the huge investments required both of equipment makers and of information providers, the first CD-I players and programs are not expected to be available commercially until 1988 at the earliest.

For all types of compact disc, digital data are stored as a series of microscopic pits and lands (flat spaces) of variable length along a spiral track on a plastic substrate. A 1-micron-wide laser beam that illuminates the surface is scattered by the pits and reflected by the lands, enabling a photodiode to distinguish between the two and thus read the encoded data. In size, a CD-ROM player resembles an add-on disk drive for a personal computer. Some CD-ROM drives can be installed to replace a conventional floppy disk drive in a personal computer, and even smaller "half-height" drives are expected to be available by the end of this year.

The main difference between CD audio recording and CD-ROM recording lies in the error detection and correction techniques. Since CD audio players convert the disc's digital data to an analog signal for sound reproduction, errors due to missing bits or surface imperfections can usually be handled by interpolation and rendered largely inaudible to the listener. But such errors could be significant for a CD-ROM. So the Philips/Sony standard defines coding that both allows CD-ROM drives to correct errors and provides addition-

The coming of the interactive compact disc

The release of provisonal specifications for the Compact Disc-Interactive (CD-I) was one of the most startling consumer audio/video announcements of 1986. Philips and Sony, the codevelopers of compact disc technology, see CD-I as the next generation of mass market devices based on CD technology. They envision CD-I being used in a wide variety of creative applications such as adventure games, genealogical studies, interactive encyclopedias, audiovisual travel guides, and vehicle navigation systems.

Although the first CD-I products probably won't appear for another 18 months, CD-I discs will be capable of storing music, speech, photographs, animated pictures and graphics, computer programs and data, and, most likely as more advanced technology becomes available, television images. All these elements are theoretically possible on one disc, promising some extraordinary multimedia programs. For example, The Record Group (Burbank, Cal.), a subsidiary of Warner Brothers, is working on several projects using the film, record, TV, and radio libraries of its parent company. One project, The Time Machine, is a political history of the world from 2500 B.C. to the present. Viewers can search through time to listen to a narration of events of a given period and watch film excerpts, photographs, animations, and graphics. Another project is a viewer-directed tour of European capitals where the viewer can also drop back in time to see Dickensian London or revolutionary Paris.

The CD-I player that will bring all this to the consumer is yet to be developed, although the Philips/Sony announcement specified some elements of the hardware and software so companies could begin working on systems and programs. As a result of the announcement, CD-I players will be based on a CD-ROM drive controlled by a Motorola 68000-series microprocessor and the OS-9 operating system developed by Microware (Des Moines, Ia.). OS-9 is a multitasking, real-time operating system used in Tandy's Color Computer and embedded in a variety of industrial control systems, automatic teller machines, and communications processors. Releasing detailed specifications early, say Philips and Sony executives, will ensure that CD-I discs will have a common format and will run on CD-I players from any manufacturer.

As with CD audio, CD-I discs will contain all the necessary application and operating software on the same disc. It's expected that interactive and audio discs will eventually play on the same CD-I device, although currently manufactured audio discs may not be compatible. Estimates of cost for CD-I players range from $1000 to $1500, considerably more than today's CD audio players. Says Robert van Eijk, marketing support manager for Philips Subsystems and Peripherals, "Our market strategy is eventually to develop a worldwide standard in which one CD player will be compatible with any of the three CD formats."

Although CD-I is generally acknowledged as an exciting new development, it is uncertain whether a profitable home consumer market exists for interactive compact disc. When interactive videodisc was first introduced in the late 1970s, it sparked optimistic predictions for a home market, but consumer programming failed to materialize and the market fizzled. Indeed, it has taken interactive videodisc almost 10 years to find a small but profitable niche in industrial training and education. The market for any type of interactive programming—videodisc or CD-I—is heavily dependent on the availability of high-quality software. Professional interactive disc programs require skilled video producers, art directors, computer programmers, and instructional designers.

Stan Cornyn, president of The Record Group, has assembled such a crew of creative talent and plans to work on as many as 50 titles during the next year. He estimates the typical program may cost around $250,000, a figure that many industry experts consider far too low since it may not include the full cost of acquiring the rights to use audio and visual materials developed by other publishers. Nonetheless, to break even, Cornyn would have to sell at least 25,000 copies of each title. Of course, CD audio, which many skeptics thought would not be able to compete with LP records and cassette tapes, has become a very profitable business. (Audio discs, however, generally use existing programming and so do not face the high initial programming costs of CD-I.)

Fortunately, the early Philips/Sony announcement gives CD-I producers a long lead time. By the time CD-I players are commercially produced, they should be able to draw on a substantial programming library.—***Judith Paris Roth***

al error data for the host computer. The drives themselves can deliver a hard error rate of up to 10^{-12}, or one error in about 200 discs. If the access software makes use of CD-ROM's error detection codes, the rates goes below 10^{-25}, or one undetected wrong bit in 2 quadrillion discs.

What the Philips/Sony CD-ROM standard does not do is specify what types of information are to be stored, or how. Thus it does not specify how to encode or compress text, graphics, audio, video, or computer programs. Nor does the standard specify the logical information to be contained on a disc—where and how to store the directory of contents, how to open and close a file, and how to identify the beginning and end of a file. Consequently, CD-ROM publishers have had to develop their own file formats and produce extensions to the most common personal computer operating systems, such as MS-DOS.

To correct this problem, an industry association called the High Sierra Group (after the site of its initial meeting) was formed to develop proposals for a standard CD-ROM logical file structure. The proposals, published in May of this year and submitted to the National Bureau of Standards and the European Computer Manufacturers Association, will allow CD-ROM applications on a PC to read data from a CD-ROM system independently of the particular operating system or hardware being used. A single logical format for CD-ROM discs will serve any hardware and software combination. In addition, discs made to the High Sierra format will be readable with CD-I systems, according to the group's chairman, John Einberger of Reference Technology (Boulder, Colo.).

The other standards issue yet to be fully resolved for the CD-ROM is the interface to be used between a drive and a personal computer. The standard RS232 serial port used on most IBM PCs and compatibles for data transfer, particularly for communications, is too slow to accommodate the 1.2-megabit-per-second transfer rate of a CD-ROM. There are several possibilities, but the leading candidate appears to be the Small Computer Systems Interface (SCSI, pronounced "scuzzy"), based on an interface developed by floppy disk drive maker Shugart Associates (Sunnyvale, Cal.), which is now used by several hard disk drive manufacturers. Philips Subsystems and Peripherals (New York) recently came out with the first CD-ROM drive with a SCSI interface, and other manufacturers are expected to follow suit shortly.

The data transfer rate of a CD-ROM is about the same as that of a high-perfor-

BOB FADER

File standards developed by the High Sierra Group, chaired by John Einberger, promise universally readable CD-ROM discs.

mance floppy disk drive—slower than most hard disk drives—but access time is much longer. The CD-ROM is slowed by the mass of its laser pickup head, which contains several lenses and requires extreme accuracy in positioning. Typically, the CD-ROM requires half a second to access the innermost tracks of a disc and $1\frac{1}{2}$ seconds to access the outermost tracks. Once the head has moved to the desired spot on the disc, sequential data can be read at the 1.2-megabit-per-second rate.

Sony and Philips are working to reduce the access time. The half-height drives to be introduced later this year by Philips are said to have an average access time of half a second. Several companies are expected to announce drives with two heads within a year. While one head is reading data the other will be making the next seek, bringing the access time closer to that of a hard magnetic disk. Continuing improvements in laser head and lens design, notably by Philips, Sony, and Matsushita, may allow data to be packed two or even four times as densely on a disc.

For $1000 or less, a CD-ROM drive offers access to huge databases previously available only on-line.

The long access time and high data transfer rate have some important implications for the organization of data on CD-ROM discs. For example, a common way of storing information on a personal computer is the relational database, typified by the popular program dBase III, in which data are stored as a series of tables. Information is retrieved through indexes that show the table, row, and column where the data are stored. These indexes have a tree structure that must be followed to locate the data. Finding a particular piece of data means following several branches of the tree, each of which would require the CD-ROM's pickup head to move. Hence a conventional relational database will perform badly on a CD-ROM unless the tree structure can be modified to reduce the number of movements.

CD-ROM DISCS

Commanwealth Agriculture Bureaux (UK)
Agriculture Database

Chemical Abstracts/DEC
Health & Safety in Chemistry
Fraser Williams/DEC (UK)
The Fine Chemicals Directory
Royal Society of Chemistry/DEC (UK)
Current Biotechnology Abstracts

Cornell University, English Dept.
Black Fiction to 1920
Interage Research, Inc.
Fast Past
Tescor
National Item Bank
Univ. of California-Irvine
TLG Language Project

Knowledge Access Inc.
Who's Who in Electronics

Grolier Electronic Publishing
Academic American Encyclopedia
McGraw Hill
Encyclopedia of Science & Technology

Engineering Information/DEC
Chemical Engineering (Compendex)
Electrical & Computer Engineering (Compendex)
NTIS/DEC
Computers, Communications and Electronics
University Microfilms
1984 IEEE Journals and INSPEC

NTIS/DEC
Environmental Health and Safety

Datext, Inc.
Corporate Database: Consumer Sector
Corporate Database: Industrial Sector
Corporate Database: Services Sector
Corporate Database: Technology Sector
CorpTech: High Technology Sector
Disclosuro, Information Group
Compact Disclosure
Dun's Marketing Services
Million Dollar Directory
Online Computer Systems
Tax Forms on Demand
Standard & Poor
PC COMPUSTAT

DataTimes
DataTimes Library System

International Computaprint Corp.
Patent Information Database
Microsoft Press
CD-ROM: The New Papyrus
NewsBank
NewsBank Electronic Index

Horizon Information Services
Reference Tool Kit: LC-LAW
Information Handling Services
Comptroller General Decisions
McGraw Hill
Shepard's Bankruptcy Citations
The Michie Company
Code of Virginia
Prentice-Hall Information Network
PHINet Tax Resource
Public Affairs Information Service
PAIS International

Access Innovations/SilverPlatter
A-V Online
The British Library *(UK)*
UK Library Database
Brodort Corp.
Le Pac: Local Public Access Catalog
ERIC/SilverPlatter
Current Index to Journals in Education (Archival)
Resources in Education (Archival)
CIJE & RIE, 1983–present
EBSCO/SilverPlatter
The Serials Directory: Int'l Reference Book
The Faxon Company
Periodical Cataloging Database
General Research Corp.
LaserQuest: GRCCOM Resource Database
H. W. Wilson
WILSONDISC
Horizan Information Services
Cataloger's Tool Kit
Iogram Book Company
LaserSearch Book Identification/ Acquisition System
Institute for Scientific Information
Science Citation Index
Librory Association Publishers Ltd. *(UK)*
LISA: Library & Info Science Abstracts
Librory Corp.
ANY-BOOK
LC MARC
Librory Systems & Services
Bibliographic Processing Network, Jr.
OCLC
CD Reference Package
CD Cataloging System
R. R. Bowker
Books in Print
Ulrich's Int'l Periodicals Dir.
Sydney Library Products (UK)
Library & Technical Service Disc (LC MARC)
UTLAS Corp.
DisCon (MARC, REMARC Conversion)
LAWMARC
PC MARC

AMTEC Information Services
OPTI/Search Sampler Disc

University af Melbourne (Australia)
Australia LDAs & Victoria CCDs

Knowledge Access
Your Marketing Consultant

APA-PsycINFO/SilverPlatter
PsycLIT
Cambridge Scientific Abstracts
Aquatic Sciences & Fisheries
Life Sciences
MEDLINE
Digital Diagnostics
BiblioMED
Elsevier/SilverPlatter
EMBASE-Excerpta Medica
Horizon Information Services
Desktop Database Service: MEDLINE-CD
Reference Took Kit: LC/STM
Micromedex
Drugdex
Emergindex
Poisindex & Identidex
NTIS/DEC
Medicine, Health Care & Biology

Engineering Information Inc./DEC
Aerospace Engineering (COMPENDEX)
Jet Propulsion Laboratory
Voyager Images of Uranus
NTIS/DEC
Aeronautics, Aerospace & Astronomy

NTIS/DEC
Energy And Natural Resources
Info. Serv. Div.–U. af Tulsa/DEC
Petroleum Abstracts: 1965–1977
Info. Serv. Div.–U. af Tulso/DEC
Petroleum Abstracts: 1978–present

Ingram Book Company
Retail LaserSearch

Sociological Abstracts/SilverPlatter
Sociofile

Library Corporatian
PC laser Library
Reference Technology Inc.
Software Library DataPlate

Optical Media Services
Universe of Sound, Vol. 1

CD Data Report. Langley Publications (McLean, VA)

Fortunately, the large storage capacity of the CD-ROM can provide some solutions to this problem. For instance, each branch of the tree can have numerous "twigs"—one for each piece of data—so the links can be performed with fewer steps. Alternatively, the data can be manipulated into a larger number of tables before storage on the CD-ROM. That way, the need to merge data by selection from a single large table can often be drastically reduced.

For textual databases, the large storage capacity of the CD-ROM allows full-text searching for a single word or a particular phrase or combination of words. Each disc can contain a full-text inversion—an index that records the position of every word in the text, discarding words like *the* and *to*. A search for a paragraph containing the term *compact disc* would involve four seek operations. The first movement would read the index for the letter *c* and the second would find the locations of *compact.* Another two movements would be needed to determine the locations of the word *disc.* Finally, the two sets of text locations would be compared to find the occurrences of *compact disc.* Full-text inversion can occupy as much space as the text itself and so has not been used with conventional personal computer database storage systems. But at a CD-ROM conference sponsored earlier this year by Microsoft of Redmond, Wash., Computer Access Corporation (Belmont, Mass.) demonstrated an inverted version of the 600-page conference book, *CD-ROM—The New Papyrus,* produced using the company's Bluefish PC software.

According to Computer Access president Jock Gill, the ASCII code of the book was inverted, the premastering tapes were prepared, and a compact disc master was produced (by Philips in Europe) within the space of 11 days. Recently, Computer Access offered a CD-ROM Publishing Evaluation Kit to allow a publisher to produce up to 50 copies of a custom CD-ROM (holding 50 megabytes of the customer's own data) for less than $10,000.

"By the end of the decade, we'll see multifunction drives for CD-ROMS, write-once discs, or erasable discs."

The costs of CD-ROM production are coming down steadily, bringing the technology within the reach of smaller publishers and businesses. According to Lawrence Schwartz, a senior project engineer at the Philips Subsystems and Peripherals assembly plant in Knoxville, Tenn., the mastering process, not including data preparation, costs approximately $3000 plus $20 a disc in quantities of 50. For a small production run of 200 discs, Schwartz estimates the unit cost to be less than $35. (For special applications, a direct disc—a single glass disc cut on a mastering machine—can be produced for about $3000.) As Schwartz points out, these numbers translate into a very low storage cost—only 17½¢ per megabyte if the disc contains 200 megabytes, versus more than $5 per megabyte for equivalent floppy disk storage.

Philips marketing executive Robert Moes envisions compatibility among compact disc formats.

RAY ELLIS

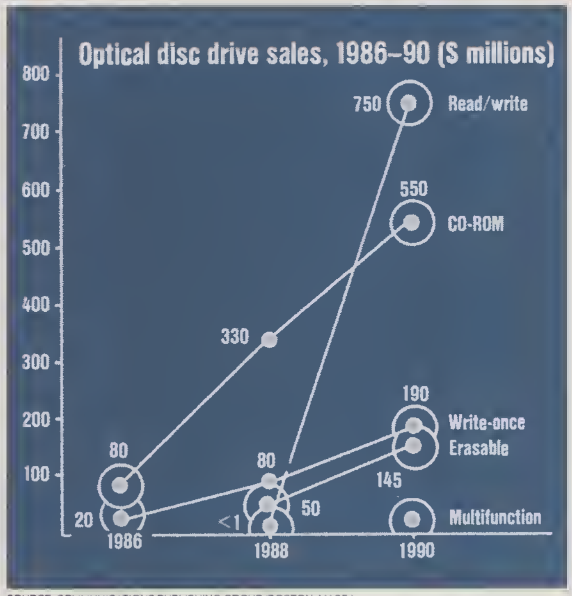
Commercially available databases vary considerably in price and complexity. The CD-ROM version of Grolier's 20-volume *Academic American Encyclopedia* sells for only $199. Digital Equipment Corp., the first computer company to supply a CD-ROM reader, offers a series of commercially published engineering and scientific abstract databases as yearly subscriptions updated quarterly, each priced around $1200. On the business side, Datext (Woburn, Mass.), a subsidiary of Atlanta-based communications and publishing conglomerate Cox Enterprises, offers a corporate information database for $19,600 per year, including monthly updates and a CD-ROM drive. For this price, subscribers get four discs containing more than a million pages of business data on some 10,000 U.S. companies, gleaned from annual reports, SEC filings, news reports, and investment analysts' findings.

Most of the commercial CD-ROM databases do little more than replicate what is already available from on-line services such as Dialog. But the CD-ROM offers the possibility of much more than simple text or numerical database storage. At the CD-ROM conference sponsored by Microsoft, the company demonstrated a CD-ROM application called The Multimedia Encyclopedia. With the addition of some sophisticated video hardware to a PC/AT, it combined text, audio, graphics, and animation in a startling display of the possibilities of CD-ROM. A search for *Beethoven* produced not only a biography of the composer but also a graphic representation of the score of one of his works and an audio recording of the same

BUSINESS OUTLOOK

Optical storage promises swift growth

Optical discs, which combine the advantages of very large data-storage capacity, tolerance of rough handling, and very low error rates, are on the verge of catalyzing a new market for mass computer storage. Three types of storage discs will be available over the next decade. The CD-ROM (compact disc read-only memory), the first variety to reach the market, stores 550 megabytes of data that cannot be altered or erased. Write-once discs, which are relatively new to the market, typically hold 1–2 gigabytes and let users store and update information without eliminating data already on the disc. Erasable discs, which are not expected to appear until 1988, permit continual reuse. All three discs are accessed by drives, which may be built into computers or purchased as add-on equipment.

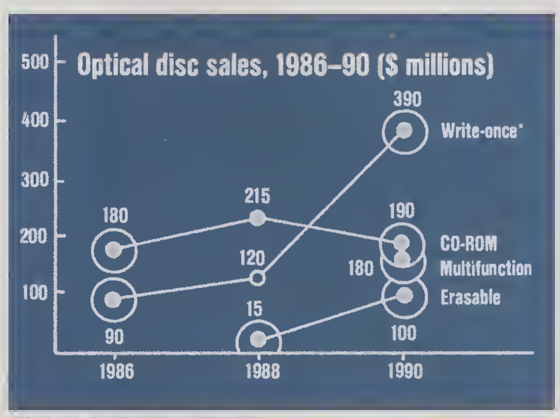


SOURCE: COMMUNICATIONS PUBLISHING GROUP (BOSTON, MASS.)

DAN COLLINS

Revenues for CD-ROM discs and drives will reach $260 million this year, according to Communications Publishing Group (Boston), while the write-once market (so far consisting of sales to OEMs only) will amount to $110 million. By 1990 these numbers should climb to $740 million and $580 million; sales of erasable discs and drives will account for an additional $245 million.

The leading manufacturers of CD-ROM discs and drives are Philips of the Netherlands and Japan's Sony, codevelopers of the technology. Other drive suppliers include Digital Equipment (Maynard, Mass.), Reference Technology (Boulder, Colo.), Denon America (Fairfield, N.J.), and Hitachi and Panasonic of Japan. LaserVideo (Chicago) and 3M (St. Paul, Minn.), among others, compete with Philips and Sony in manufacturing and mastering discs. Optical Storage International (Santa Clara, Cal.) and French-owned Alcatel Thomson GigaDisc (Franklin, Mass.) head the list of write-once disc suppliers, while the most prominent drive vendors include OSI, Xerox's Optimem (Sunnyvale, Cal.), and Optotech (Colorado Springs, Colo.). Leaders in the development of erasable disc technology include Verbatim (Sunnyvale, Cal.), IBM (Armonk, N.Y.), and many of the Japanese firms involved with CD-ROMs.



*INCLUDING SHIPMENTS TO READ/WRITE DRIVES

CD-ROMs are presently most successful in applications requiring the long-term storage of large amounts of unchanging information. The discs' great storage capacity offers a major space-saving advantage, while the integrity of information carried on the disc is ensured by its read-only technology. CD-ROM users include libraries, which are putting whole card catalogs onto discs; banks and insurance companies, which rely heavily on records of past customer activity; and newspapers, whose morgues contain copies of every back issue. Commercial CD-ROM databases have begun to appear from several companies, including Digital Equipment, Knowledgeset (Monterey, Cal.), and Datext (Woburn, Mass.), offering potential competition with firms that distribute electronic databases to subscribers over long-distance telephone lines.

The market for CD-ROMs should maintain its strength into the next decade. At the same time, write-once discs will open up new segments in paper-intensive businesses by letting users do more than just archive large amounts of information. "Insurance companies and credit unions, for example, can use write-once discs to store documents electronically before they are ever used," says David Seigle, marketing director of FileNet (Costa Mesa, Cal.), a firm that produces a document-image processor for use with optical discs. "These documents can then be automatically sorted, forwarded, filed, and annotated."

Erasable discs will appeal to users needing the erasability of magnetic media and the capacity of optical discs. "Engineers and architects could refine blueprints or floor plans stored on erasable systems," says Jeffrey L. Swartz, president of Communications Publishing Group. Write-once discs would still be needed, however, to create an audit trail of an evolving design that could not be accidentally erased and that would not require a backup record.

This prospective use of two optical disc technologies in tandem could become increasingly common. Some suppliers are already developing drives that will handle more than one kind of disc, and may even be able to combine magnetic and optical techniques. "A read/write drive—one that can be used with CD-ROMs and write-once discs—should be the first step in this direction," says Louis Giglio, technology market researcher at Bear, Stearns (New York). "The flexibility such a device would give users in storing, recording, and manipulating information should greatly boost demand for optical discs." ***—Steven Weissman***

WILLIAM JAMES WARREN

Compact Disc-Interactive programs now in the works will let the viewer step through history or take a self-guided tour of Europe.

composition. Similarly, a search for *DNA* produced a description of cell structure and an animated view of a DNA helix appearing simultaneously in windows on the computer display. Microsoft's encyclopedia was only a demonstration and, because of the huge investment that would be required to complete it, is unlikely to be offered as a product, says the company.

The encyclopedia demonstration showed animation but not full-motion video. Although the CD-I standard allows for a small image in motion within the display screen, the data transfer rate of a compact disc drive is currently too slow—and the capacity of a disc to store color video in digital format is too limited—to support full-motion video. One second of digital color video on a compact disc would require about 30 megabytes, whereas a second of analog color video on a LaserVision videodisc takes up little more than the equivalent of 1 megabyte. Thus a 12-inch Laser-Vision disc can record up to 60 minutes of video. If the same analog technique were used on the much smaller compact disc, the result would be only about five or six minutes of full-motion video.

The answer to this problem will lie in the use of specialized digital signal processing for the video signals, says Brian Brewer, president of Earth View (Ashford, Wash.), a developer of multimedia software. For example, it's not necessary to store every bit of data in every frame. To reproduce successive frames, all that's required is to store the differences from one frame to the next. This type of video compression has been demonstrated by Evital (Dallas) with a system capable of storing up to two hours of digital video on a single CD-ROM disc. Brewer also points out that a satisfactory alternative might be to combine a CD-ROM with a videodisc player. The CD-ROM disc would contain an index for keying the videodisc to provide the video signals to a personal computer or a TV monitor.

Despite the various limitations of the CD-ROM, industry experts are optimistic about its future. "Every personal computer will have a CD-ROM drive built in by 1990," claims Robert J. Moes, director of marketing for Philips Subsystems and Peripherals. IBM is said to be purchasing large numbers of CD-ROM drives for evaluation and has a significant research program on optical memories. "By the end of the decade, we'll see multifunction drives capable of using CD-ROMs, write-once discs, or erasable discs," says Edward S. Rothchild, a San Francisco–based optical memory consultant. He predicts that the larger and less expensive storage capacity of optical discs will eventually bring about the replacement of magnetic disks. "Optical media will democratize the availability of information," he says. "On-line database services account for only $300–400 million in revenue today; CD-ROM could make database publishing more than an order of magnitude greater." □

Jeffrey Bairstow is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*

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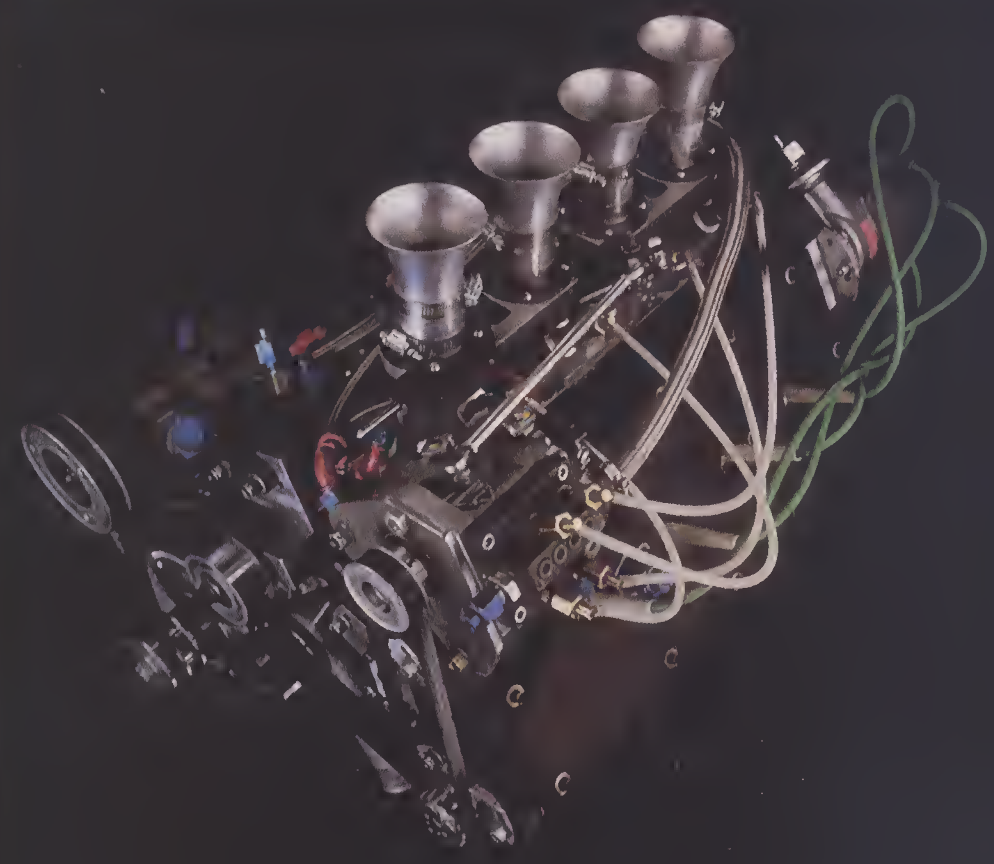


HIGH-PERFORMANCE PLASTICS

Novel combinations of materials are finding niches in automaking, electronics, and food packaging

Plastics are finally getting some respect. Once regarded as flimsy, throwaway substitutes for costlier materials, the new generation of high-performance plastics (also called engineering resins) are often tougher and more durable than the "real thing."

Cars with plastic bodies, for example, are lighter and more corrosion-resistant than their all-steel counterparts; chips insulated with plastic may help computers achieve far greater circuit densities than possible with today's glass and quartz materials; foods packaged in new aseptic "barrier" resins that keep out air, moisture, and germs can be popped into the microwave oven in their containers, something not possible with foods in tin cans; and semiporous plastic films are being engineered to separate virtually any type of molecule from a complex solution.

by Gordon Graff

Although the new materials still face some lingering resistance from cautious designers, the spate of new outlets has generated high hopes among producers. "This is a very exciting business to be in right now," says Charles R. Eggert, manager of market development at Monsanto Chemical's plastics division in St. Louis. In fact, industry consultants Charles H. Kline and Co. (Fairfield, N.J.) estimates that by 1991, worldwide sales of all engineering resins will be $8.3 billion in 1986 dollars. Sales this year are expected to reach $5.8 billion.

Made almost entirely of plastic, the lightweight racing-car engine above may one day be modified for conventional passenger autos.

The renaissance in plastics stems not so much from the development of new polymers as from the mixing and matching of different types of existing polymers—such as nylon, polyesters, polycarbonates, or polyphenylene oxide—or from their combination with reinforcing fillers such as glass, metal, or carbon. These innovations are enabling the industry to come up with a steadily expanding menu of novel properties. Some of the new materials are stronger than steel; others are electrically conductive, or stable at temperatures that would have melted older plastics.

Such properties come at a price, of course. While older commodity plastics such as polyethylene, polypropylene, and polyvinyl chloride generally sell for under $1 a pound, the new resins command up to $15 a pound—prices that could spell important new profits for producers beset by lackluster commodity sales. But the ultimate beneficiary is "the end user who doesn't want to worry about product recalls or customer problems," says Bennett Nathanson, manager of commercial research and new business development at Celanese's engineering resins division in Summit, N.J.

Coming: a $10 billion market. The advances in plastics technology are especially attractive to the auto industry, which has ambitious plans to boost the amount of exterior plastics in its cars. Older resins on the inside of the car, meanwhile, are rapidly giving way to superior new ones. With a few exceptions—the Corvette and the Pontiac Fiero, for example—most cars still have steel bodies, but Detroit is moving inexorably toward plastic body panels and bumpers. In fact, as many as 70% of new cars will sport plastic body panels by the year 2000, according to a recent University of Michigan study; only about 5% of today's new cars are so equipped. At Du Pont's polymer products department in Wilmington, Del., R&D director Richard G. Bennett interprets that as a future $10-billion-a-year business for resin suppliers.

The most obvious reason for the switch to plastics is weight reduction—700 pounds worth in the case of an experimental GM "concept car" in which metal exteriors were replaced by plastics. But automakers note other advantages, including corrosion resistance and the ease of styling changes. Plastics could also prove to be less labor-intensive, since a metal part assembled from many smaller pieces can be replaced with a single molded plastic component. Plastics also permit configurations that would be impossible with other materials, such as the increasingly common forward lighting systems made of polycarbonate lenses contoured with the rest of the car body. Glass lenses would be more vulnerable to shattering if incorporated into the vehicle body.

Still, Detroit has been slow in converting to all-plastic vehicles. One reason is that such conversions require "quite a bit of retooling," notes Irvin E. Posten, manager for composites in GM's engineering department. As a result, only a few "dedicated" plastic car plants have been built.

Among the products of these factories is what many consider to be the prototypical plastic car—the Fiero, which debuted in 1984. The hood, roof, deck lid, and upper-rear quarters are made of sheet-molding compound (SMC), a rigid composite consisting of a polyester resin reinforced with glass fibers. The door panels, bumpers, and bumper cushioning are made of polyurethanes fabricated by reaction-injection molding, or RIM, in which liquid precursors of the plastic react inside the mold to form the finished part. And the rocker panel (along the lower edge of the body) and lower-rear quarter panels use a variety of thermoplastics (the general name for materials that are pumped into a mold in liquid form and solidify upon cooling).

By mixing and matching various polymers and fillers, producers offer resins with a broad range of properties.

Although the Fiero's exterior is all plastic, the underlying frame is still made from steel. Automakers hope eventually to change that as well, but "structural components made of plastic will take a lot more development work than the exteriors," says Marilyn Perchard, principal engineer for plastic materials at Ford (Dearborn, Mich.). The reason, she adds, is that the frames bear critical loads and that the plastics involved would "require different processing parameters" from those in the exteriors.

Not all the bugs have been worked out of the technology for plastic exteriors either. For one thing, it is hard to find thermoplastics that will stand up to the 400° F ovens used to cure anticorrosion coatings on the rest of the exterior, which is still largely made of steel; this step is followed by the finish coat, which requires subjecting the auto body to temperatures of about 300° F.

While the SMC used in large panels can take these temperatures, the thermoplastics found in bumpers and doors normally can't. Affixing a plastic part such as a bumper after the anticorrosion treatment but before the painting won't do, because the entire assembly line would have to be retooled. So the bumpers, which are often made of polycarbonate/polyester alloys, are usually painted separately, then attached near the end of the production line. To avoid this costly step, the auto industry is seeking plastics that can be affixed early on and then left to go through the ovens. Ford is looking at one such heat-resistant resin for the bumpers of its Taurus—a nylon/polyphenylene oxide (PPO) alloy made by General Electric. Perchard calls the material, tradenamed GTX, "very promising." Another heat-resistant GE product, an alloy of PPO and polyesters, is being evaluated by Ford for door panels.

An additional problem is that SMC's cycle time (the time it takes to stamp out a finished part) is two to three minutes—rather slow by auto industry standards. Automakers are also hindered by SMC's high porosity, which makes painting difficult, and by the glass fibers that typically are visible on the surface.

While thermoplastics have far better surface characteristics, they are usually not strong enough to compete with SMC for horizontal panels (hood and roof) and are therefore confined to vertical panels such as doors and fenders. But GE and PPG, the Pittsburgh-based chemical producer, recently joined forces to make a stampable grade of fiberglass-reinforced thermoplastic sheet suitable for horizontal sections. According to Herbert K. Hoedl, a general manager in GE's plastics division (Pittsfield, Mass.), the new sheet not only equals SMC's performance "but exceeds it in many cases." He notes further that the cycle time for the material is under one minute and that it withstands the searing oven temperatures used with steel and SMC. The product is set for commercial introduction later this year.

Auto headlamps are also receiving plenty of attention. The new streamlined polycarbonate designs that are showing up in many late models are decidedly more rugged than glass; however, they have some problems of their own. For one thing, ultraviolet light from the sun causes polycarbonate to become brittle; the plastic is also heat-sensitive, so it must be placed quite far from the light bulb fixtures.

Celanese thinks it has the answer to these limitations: a new resin called polyarylate. Formed by a reaction of

the monomers terephthalic acid and isophthalic acid with the chemical bisphenol A, polyarylate is more UV- and weather-resistant than polycarbonate. It also stands up better to heat, allowing a lens to fit closer to a light bulb. Says Robert H. Jackson, director of business development at Celanese's engineering resins division, "we've had a tremendous response" to polyarylate from potential customers in the automotive, aerospace, and other sectors.

Under the hood, plastic parts have been introduced piecemeal over the years for a variety of fuel-handling, mechanical, and electrical applications. But one small New Jersey company has built an entire engine predominantly out of plastics. The engine, a V-6 turbo for racing cars, makes extensive use of a stress- and heat-resistant material tradenamed Torlon by its maker, Amoco Chemicals (Chicago). The 2-liter, twin-cam, 4-cylinder engine, built by Polimotor Research (Fairlawn, N.J.), weighs only 200 pounds, about half as much as its all-metal counterparts; it uses plastics nearly everywhere but in the immediate vicinity of the combustion chamber.

Although the engine has thus far powered only racing cars, Polimotor president Mathew Holtzberg predicts that "it may also appear in passenger cars before long." GM's Posten, however, notes that few tests have been done on the engine's performance in passenger cars, so "it may be quite a while" before it is adapted for that purpose.

Staking out electronics. Plastics are also expanding their role in electronics. Polymer photoresists have long been used in fabricating integrated circuits, and almost all electronic equipment is packed with plastic circuit boards. But the new engineering plastics are expected to be used as chip insulation layers, optical fiber components, and data storage discs.

The need for new insulation materials for electronic chips becomes more critical as circuits grow in density and complexity. The interconnection lines on these chips typically consist of several levels of metal conductors with insulation between them. A layer of glass or quartz is usually deposited on each level of circuitry before the next level is laid down; but glass and quartz often harden with tiny bumps on top, making it harder to lay down the new lines and increasing the possibility of short circuits between the layers. As a result, electronics firms are searching for a polymer that would "planarize"—that is, form a completely flat surface when deposited. Such a material would also have to be a good insulator and be capable of withstanding high temperatures; the deposition of vaporized metal can heat chip surfaces to more than 700° F.

Closest to meeting these needs are a class of materials called polyimides, says James Economy, polymer science and technology manager at IBM's Almaden, Cal., research center. He is confident that polymers will be developed to meet all the requirements.


MARC CORSON

A polymer can be designed for applications ranging from phones to wheel covers, says Monsanto's Charles R. Eggert.

Electronics manufacturers are also interested in polymers that would improve the way chips are mounted on circuit boards. Right now, chips are usually mounted on a ceramic module, which is itself attached to the board. However, the different rates of expansion and shrinkage of the silicon and ceramic when exposed to repeated heating and cooling during processing cause stress at the point of attachment, which can lead to weakened connections and subsequent failure. Also, ceramics tend to slow down the flow of electrons in the wires embedded in them, reducing circuit speed. Electronics researchers thus hope to find polymers for the modules with the same thermal expansion characteristics as silicon, thus reducing strains during processing. Such materials should also speed the flow of electrons in the embedded wires. Again, IBM researchers are studying polyimides for this application, although Economy notes that his staff hasn't yet found the ideal material.

Growth in optical discs. Plastics will also play a prominent role in the optical disc technology that is expected to blossom in the 1990s. Today's laser-read audio compact discs are the best-known example of optical discs, but ultrahigh-capacity optical data storage discs—known as CD-ROM (read-only memory)—are now arriving on the computer scene (see "CD-ROM: Mass storage for the mass market," p. 44). A single 4.7-inch disc can hold some 550 megabytes of data, equivalent to 28 20-megabyte hard disks or 1500 360-kilobyte floppy disks. Both audio and computer versions are typically made of polycarbonate plastic coated with an aluminum layer; information is encoded on the aluminum surface in the form of tiny pits that can be read by a laser beam.

The growth of audio and computer optical discs could bring parallel growth in the polycarbonate resins that go into them. In fact, companies such as Du Pont, Dow (Midland, Mich.), GE, and Mobay (Pittsburgh) are boosting production of such resins to cater to the disc market, which Du Pont estimates will reach $4 billion by 1990.

Future developments could put a crimp in this otherwise rosy picture, however: the next logical step in the evolution of optical discs—an erasable format for audio, video, and computers—may not be able to use plastics at all. One erasable system that is being considered by developers including IBM, 3M, Eastman Kodak, Control Data, and Xerox is a technology called magneto-optic recording. These systems rely on a laser beam that writes data on a magnetic film—typically consisting of rare-earth mixtures such as terbium-cobalt-nickel—deposited on a substrate. The problem is that if the substrate is made of polycarbonate, the magnetic films rapidly degrade when

BUSINESS OUTLOOK

Autos and electronics drive the plastics boom

High-performance plastics (also called engineering resins)—which include such materials as high-grade nylon, polycarbonates, polyimides, acetals, and thermoplastic polyester—are finding growing use in a variety of commercial applications. The electronics industry accounted for 30% of the total of 839 million pounds of engineering resins sold in the U.S. last year, according to the Society of the Plastics Industry, a New York–based trade group. Transportation (primarily autos, but also aerospace) made up 17% of the total, followed by building and construction (9%), industrial machinery (4%), and packaging (2%). About 24% of U.S. engineering resins are exported.

A boom in plastics use in autos and electronics in the next few years should push the production of engineering resins from a worldwide volume of 3.5 billion pounds this year (worth about $5.8 billion) to around 5 billion pounds (worth $8.3 billion) by 1991, according to Peter Gavrushenko, project manager for Charles H. Kline (Fairfield, N.J.), a market research firm.

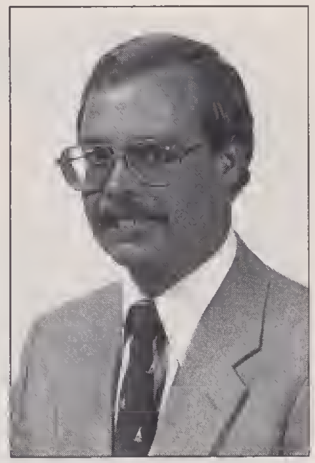
This expansion will be a boon to engineering plastics producers. In the U.S., companies with a broad product line include Du Pont (Wilmington, Del.), Celanese (New York), Dow Chemical (Midland, Mich.), Monsanto (St. Louis), and General Electric (Pittsfield, Mass.). Important overseas manufacturers with U.S. facilities include ICI, Hoechst, and Mobay.

Among automakers, the chief attractions of plastics are lighter weight and less corrosion than metals, ease of fabrication, and amenability to styling changes. Ford, General Motors, and Chrysler all have ambitious programs to replace metals, glass, and other traditional materials used in their vehicles, with plastics. Fenders, doors, and wheel covers will be new applications for some plastics. But the largest single use of plastics will be in car body panels, rising from 10–20 million pounds this year to 300 million pounds by 1995, according to Roger K. Young, a manager for engineering thermoplastics at Dow Chemical.

Electronics will be another key outlet, particularly in circuit boards, chip insulation and packaging, and new products such as optical discs. The extreme heat and electrical resistance of some of the engineering resins is a prime factor in their growth, particularly as circuits continue to grow denser. The new plastics will edge out such traditional materials as glass and quartz insulation, as well as some older plastics such as epoxies used in circuit boards. The net result is that last year's worldwide production of 25 million pounds of heat-resistant engineering resins for electronics will grow at a healthy 10% a year over the next decade, according to Carl H. Eckert, director of the materials group at Kline.

"The use of plastics to replace metals in auto body panels is the hottest area in the plastics industry today."

Roger K. Young
Technical Manager
Engineering Thermoplastics
Dow Chemical



Several new markets are opening up for producers of engineering plastics. For example, new food packaging could consist of shelf-stable "barrier" resins. These sturdy plastic laminates, which keep out air, moisture, and germs, are already used to package ice cream, catsup, and other foods. And "all you have to do is look at a supermarket shelf and you see all sorts of new opportunities for barrier resins," says Thomas H. Lyon, market development manager for specialty plastics at Dow Chemical. He envisions them replacing cans and bottles in pre-prepared single-portion servings that can be heated in their own containers. Such packages could replace some $16 billion worth of cans and bottles annually by the year 2000, estimates Richard G. Bennett, director of research and development at Du Pont's polymer products division.

"The pace of invention of totally new polymers has slowed down dramatically. What we're seeing is ways to combine existing polymers to get unique properties."

Charles R. Eggert
Manager of Market Development
Monsanto Chemical

Plastic membranes that are semipermeable (allowing only molecules of certain sizes to pass through) are another promising outlet for engineering resins. They are already used to separate hydrogen from refinery gases, to separate pollutants from waste water, and to desalinate seawater. They're also being adapted for citrus juice concentration, generating nitrogen for industrial purposes, and as containment media for genetically engineered microbes in commercial biotechnology. As a result, the 10–15 million pounds of engineering resins now used worldwide in separation membranes should grow by 15% annually over the next 10 years, predicts Kline's Eckert.

Engineering resin makers are also keenly aware of the opportunities for plastics to replace plastics. Among the chief trends here are the growth of thermoplastics, which can be melted and remolded repeatedly without physical or chemical damage, at the expense of thermosets, which harden irreversibly when heated and thus cannot be recycled. "If you look at the possibilities for thermoplastics to replace thermosets such as epoxies and phenolics, that's a 400- to 500-million-pound-a-year opportunity in the electronics field alone," says John R. Dole, Celanese's market supervisor for electronics.—***Gordon Graff***

exposed to air and moisture. So some method of depositing the films inside hermetically sealed glass discs is being examined as an alternative, even though this precludes flexibility and adds to the cost. Some developers such as 3M say plastic magneto-optic discs will be feasible, perhaps with some protective "passivation" coating on the surface. But according to IBM's Economy, the jury is still out.

Locking out germs. In the field of food packaging, plastics may prove a lightweight alternative to cans and bottles. Such firms as Du Pont, Dow, Monsanto, and Allied are vying to introduce new barrier resins that are impervious to air, moisture, and bacteria; some traditional food packagers—Continental Can and Britain's Metal Box, for example—and food processors such as Campbell Soup have also entered the fray.

While details vary, the new resins designed for shelf-stable packaging of perishable foods are generally used as laminates, with each layer designed to do a different job; Heinz's squeezable catsup bottle, for example, has six layers. A typical barrier film might consist of a support layer of polypropylene secured to a sheet of polyethylene, which is in turn bonded to a barrier plastic such as polyvinylidene chloride or ethylene vinyl alcohol, which bars air and germs. This layer is bonded to a sheet of rigid polystyrene. The layers are assembled by a process in which each polymer is liquefied and forced through a die; the streams are then combined in a single chamber which forces the hot laminate through another die that spreads and compresses the mixture into the final structure.

Producers are burdened somewhat by the fact that barrier-resin technology is basically mature; it is already familiar in the form of disposable containers for yogurt, ice cream, and TV dinners. Industry observers thus say that further growth hinges on consumer acceptance in the all-important shelf-stable applications such as single portions of soups, stews, and other prepared foods that can be microwaved right in their containers. Many of these products, which remain stable at room temperature for up to three years, are now being test-marketed.

Choosy membranes. Plastic films are also being designed to separate liquids, gases, and solids. During the past decade, semipermeable polymer membranes (which pass only molecules or particles of certain sizes) have been pressed into service for separating hydrogen from waste gas streams, desalinating seawater, removing toxic metals from municipal waste water, separating enzymes from microbial broths, and slowly releasing drugs through the skin. Many of these membranes, composed of such materials as triacetates, aromatic polyamides, and polypropylene, can be spun into hollow fibers to maximize surface area. Among the leaders in the separation membrane industry are Monsanto, Dow, Du Pont, and Celanese. Some specialized separation products are sold by smaller firms such as Pall Corp. (Glen Cove, N.Y.) and Alza (Palo Alto, Cal.).

But the action in separation membranes is more in developing new markets for existing materials than in finding new ones. In one instance, both Dow and Permea (a Monsanto subsidiary) are pushing inert gas generators—membrane systems that separate nitrogen from air or combustion exhausts to create a nonreactive, oxygen-free gas mixture. Dow is touting its unit for such tasks as blanketing inflammable chemicals or providing an inert atmosphere for treating metals at high temperatures. Permea's objective is to set up systems on offshore drilling platforms and pump the generated nitrogen into undersea oil reservoirs to prevent the platforms from sinking as the oil is withdrawn. Another proposed application: generating nitrogen that could be used to blanket fuel tanks on military aircraft to prevent fires in case of a crash.

Celanese, too, is extending the range of its separation membranes, which are based on polypropylene with microscopic pores. One major outlet for the membranes (tradenamed Celgard) will be biotechnology separations, says Henry T. Taskier, development associate in Celanese's separation products division. In one system, he envisions genetically altered bacteria growing inside the hollow fibers, fed by nutrients that seep into them; the enzymes or other microbial products would slowly diffuse out of the fibers for collection. The advantage of such a system, Taskier explains, is that the bacteria wouldn't have to be separated from the product—a costly step in many such processes.

Despite the rapidly growing applications of the new plastics, producers aren't deluding themselves: many of the ideas are, and will continue to be, a tough sell. While separation membranes and other specialized applications face few of the ingrained prejudices against plastics, the resistance is more intense in cases where plastics are trying to edge out such well-entrenched materials as metals and glass.

One reason is that even today's tough high-performance resins are saddled with the image of cheapness that still clings to the inexpensive commodity resins. Another is the all too common reluctance of designers and engineers to chuck the familiar in favor of the new. "Many of the companies that have been around for 50 or 100 years are very conservative," says Monsanto's Eggert. "What I tell them is that there's no such thing as a bad plastic . . . only a bad application." □

Practically the entire exterior of the Pontiac Fiero consists of a rigid composite of polyester and glass fiber.

Gordon Graff is a former senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*

CAN A.I. RELIEVE MAINFRAME BOTTLENECKS?

Expert systems for performance monitoring show promise, but have their limitations

by Terry Feldt

With mainframe computer systems costing $1 million or more, corporations purchasing them want to be sure the machines work at their best. Performance guarantees are hard to come by, however, since the way a system is configured and the applications it runs can greatly affect its efficiency.

For some time, a variety of software vendors have produced tools to monitor computer performance and help in system reconfiguration. Many of these firms are now turning to artificial intelligence, in the form of expert systems, to create more powerful products. But some observers claim that most expert-system products are still "vaporware"—announced but not yet on the market—and at least one leading vendor believes expert systems can play only a limited role in performance monitoring and capacity planning.

Expert systems attempt to mimic computer operators by incorporating knowledge—in the form of straightforward facts, relationships between them, and rules to manipulate them—about a computer's configuration and operating characteristics. Unlike software packages that simply collect data or permit only fixed, automatic responses to certain situations, expert systems allow great flexibility. Like human operators, they can choose among multiple courses of action depending on the circumstances and, in theory, can make educated guesses about appropriate actions in novel situations.

The field of mainframe monitoring and configuration contains several categories of products. At one end are performance monitoring tools that make a computer its own watchdog by instructing the system to collect raw data about itself. These system-level monitors measure the loads on, and the performance of, the central processing unit and its input/output channels, its main memory, and the numerous peripheral devices that store, print, and communicate huge amounts of information. The most basic performance monitors, which simply collect data and present them to a computer operator, have no need for the analytic technology of expert systems.

Nevertheless, performance monitors have been growing in sophistication and ease of use, and now commonly present their statistics in graphic as well as numeric form. "The operator does not have time to look at details," explains William Maclean, corporate program manager for system software at Burroughs (Detroit), maker of a chart-oriented performance monitor called BARS. Another vendor, Candle Corp. (Los Angeles), markets a variety of monitors for IBM mainframe operating systems and applications. Product features include visual and audible alarms that warn of impending problems, as well as the capability to monitor computer response times to user queries and to identify performance bottlenecks.

A common problem with performance monitors is that the great quantities of data they collect sometimes overwhelm computer operators and analysts. As a result, some products have begun to automate the decision-making process by permitting minimum threshold performance levels to be set. When these are passed, automatic correction procedures can be triggered.

One such product is the Explore/VM package from Goal Systems International (Columbus, Ohio), which can implement corrective software routines automatically. With Explore/VM, a data center manager can define warning points and write procedures to be invoked when the warning points are exceeded. Typically, the procedures first gather additional data on what might be

BRIAN SMITH

BGS Systems' Russell says expert systems can probably assist in capacity planning, but he doesn't believe they can do the job alone.

causing the problems. Product developer Doug Plunkett admits that this feature falls short of a true expert-system capability, but calls it "a small step in that direction."

A third product category—and the one where expert systems hold the most promise—is capacity planning and configuration management software. Such software applies various algorithms to the data generated by the performance monitors in order to produce a model of the computer and its operation. It lets analysts spot problem areas, plan system upgrades, and simulate how different system modifications will affect overall performance. It's in analysis and planning that some companies claim to offer expert-system support to computer operators.

"With traditional configuration packages, it's up to the analyst to sift through the collected data and determine what figures are good or bad and understand how to correct the bad ones," says George J. Febish, sales manager for International Systems Services (New York), supplier of an expert system–based configuration product called ISS Three. "The expert system runs through the various solutions and provides recommendations for change."

Designed for use with IBM mainframes, ISS Three consists of two components: the $10,500 MVS Analyzer, which runs on the mainframe and collects performance data, and the $18,000 Capacity Planner expert system, which runs on a personal computer linked to the mainframe. Raw data from the large computer are downloaded to the PC-based expert system, which makes real-time recommendations for configuration changes and also provides long-range forecasts. The product evaluates not just the likely effect of recommended changes but also their cost, so if two fixes would result in about the same performance improvement, the Capacity Planner would suggest the least expensive one.

Like most expert systems, the Capacity Planner is based on if/then rules, such as "If the utilization of a certain device goes over a certain level, then there are potential performance problems." The system has about 2000 decision points it can branch through as it performs analyses and makes recommendations. The rule base itself is fairly stable, according to ISS's Febish, but he notes that human experts sometimes disagree on danger levels and appropriate corrective action. For example, in the if/then situation above, some system managers might believe problems could develop when the device utilization reaches 35%, while others might think they won't occur until it reaches 50% utilization. To accommodate such differences, the Capacity Planner has an interface that lets users customize the expert-system operation to reflect their own analyses.

Expert systems can analyze computer performance data and recommend configuration improvements.

The ISS Three, with its integral expert system, has sold well to large data processing operations that already use competing software to collect and report performance data, says Febish, who notes that ISS Three can interface with many of these products and utilize their information. But the product has also been popular with smaller data processing shops that don't have the expertise to do capacity planning themselves, he says. "As they grow and acquire more costly hardware, they start looking for software that will help them recommend changes."

Another configuration product based on expert-system technology is a product from General Research (McLean, Va.) for tuning the VMS operating system run by Digital Equipment's VAX computers. Called TIMM-Tuner, the product costs $5600 for a single license and contains 17 knowledge bases networked together. When tuning the VMS operating system, system managers must set over 150 parameters, many of which must be regularly adjusted because of varying computer configurations and usage loads. TIMM-Tuner first collects data on system performance and produces summary reports and initial analyses of the configuration. The system manager then conducts an interactive session with the expert system, which gives advice on solving problems. Once the manager makes the recommended changes, the package measures their effectiveness and graphs "before and after" performance.

Independent software suppliers aren't the only ones looking into expert-system solutions to performance monitoring and capacity planning. IBM has been developing an expert system called YES/MVS at its T. J. Watson Research Center (Yorktown Heights, N.Y.). YES/MVS can issue commands directly to a mainframe computer to correct performance problems. Or it can simply advise the operator on what to do and why. IBM considers it necessary to permit operators to override the expert system, believing that large data centers will be reluctant to place operations under total software control until the packages have a proven track record. IBM has not announced when the product will become commercially available.

Control Data Corp. (CDC) in Minneapolis also has an in-house project under way. The company is using a PC-based expert system to tune its Cyber 180 mainframes. The software is intended first for use by CDC's own field service analysts, but it will eventually be sold to customers, according to Gordon Syms, a consultant and computer analyst at CDC's Canadian Development Division in Toronto.

Despite all the expert-system activity in this area, however, some observers warn that the AI technology has its limitations. "Expert systems have great allure; they're intriguing and exciting," says Donald A. Russell, VP of mainframe systems at BGS Systems (Waltham, Mass.), a leading vendor of capacity planning products. But, he says, five factors influence the accura-

cy of capacity planning—data quality, data completeness, the quality of modeling algorithms, the completeness of algorithms, and the performance observation period. Russell points out that expert-system technology can't make up for bad data or bad modeling algorithms, and can have no effect on the period of time chosen to monitor the computer for the baseline model.

The one area in which it can help, he says, is that of incomplete data. "If the base data you're monitoring are missing a key factor, then expert systems can extrapolate from the existing data to fill in the holes," he says. On the other hand, using expert systems to make up for missing algorithms can be dangerous, Russell claims, since it involves creating "fudge factors" to substitute for good algorithms. A fudge factor may be accurate for one level of computer loading, he says, but it will rarely work well across a spectrum of operations scenarios.

As a result, BGS has examined the application of expert systems to make up for incomplete data, but not to assist the other aspects of capacity planning. The company will soon introduce enhancements to its BEST/1 capacity planner that might appear to be expert systems, but are more accurately described as "guided systems," Russell says. Guided systems direct the user through logical steps of analysis and draw things to their attention, but don't come to conclusions about the best course of action. In fact, Russell says, many of the so-called expert systems in the works are actually guided systems.

Semantics aside, there is little question as to the benefits of automating mainframe computer management, according to Peter Levine, program director of the software management strategies service of The Gartner Group (Stamford, Conn.). "There is a huge market for YES/MVS, or products closely resembling it," he says. But Levine also advises buyers to be skeptical of products that claim to incorporate expert systems. "Most of these products exist as prototypes only," he cautions. "In the fields of performance monitoring, operational management, and capacity planning, anybody who can spell 'expert systems' is trying to use it in their advertising." □

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DO-IT-YOURSELF HEALTH MONITORS

Electronic sensors are quickening the pulse of the home care market

Microelectronics is bringing a wide range of sophisticated medical testing devices out of the physician's office and hospital laboratory and into the home. Accurate and reliable products that do everything from monitoring hypertension to checking blood sugar are available for considerably less than the cost of an office visit. Electronic home care products accounted for almost $1 billion in sales in 1985 and should reach $2 billion by 1988, according to Creative Strategies (San Jose, Cal.).

Probably the fastest-selling items are digital fever thermometers that give a reading in just 30 seconds, compared with several minutes for conventional mercury thermometers. More than a dozen different models are currently on the market, with total annual sales topping five million units. Within five years, that figure is expected to double.

At the heart of a digital thermometer is a small, plastic-encapsulated thermistor that changes electrical resistance in a known manner with temperature. The thermistor is hooked to a microprocessor, which is preprogrammed with a temperature curve. As the thermistor heats up, the microprocessor consults a set of reference curves and estimates the body temperature. A few years ago, hospital units that worked that fast cost $300. Today's digital home models are available for less than $20.

Each year in the U.S., millions of people suffer strokes and heart attacks that might have been avoided had they taken steps to lower their blood pressure. Self-diagnosis of hypertension has become far easier with the recent proliferation of inexpensive electronic blood-pressure monitors. Basic units cost less than $100; more sophisticated models, with automated inflation and deflation, memory, and a thermal printout, are priced as high as $250.

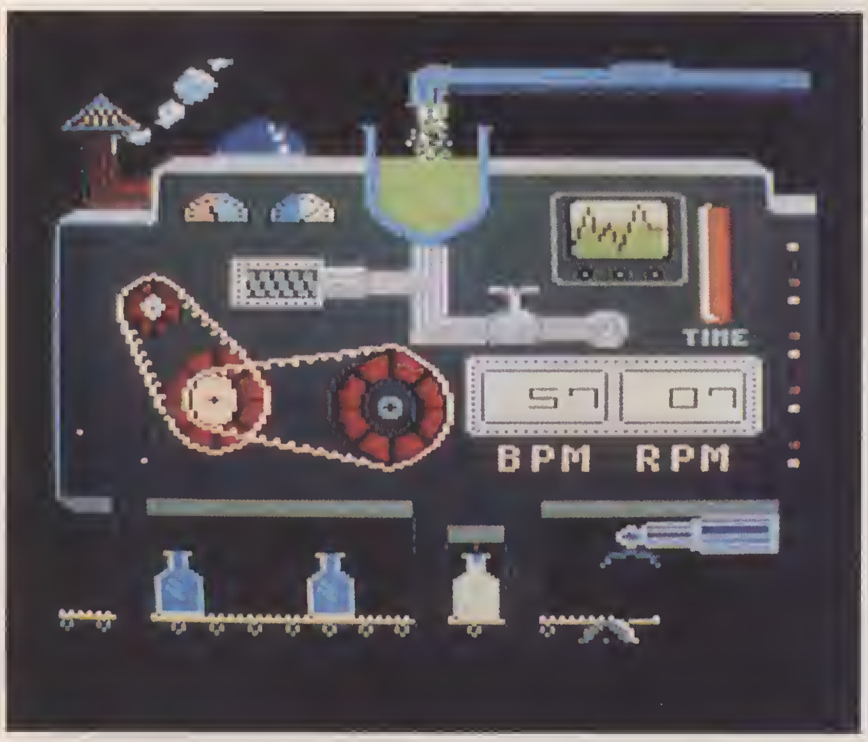
Two numbers are associated with blood pressure. The first and higher is the systolic reading—the maximum pressure in the major arteries when the heart contracts and pushes blood through them. The second (diastolic) reading indicates the lowest pressure in the arteries just before the heart starts to contract. An estimated 50 million Americans have hypertension, which the American Heart Association defines as blood pressure exceeding 140/90.

To use an automatic monitor, the patient needs to position the cuff so that a built-in microphone sits directly over the arm's main artery. When the microphone "hears" the blood rush through the artery, the unit takes the systolic reading. Pressure is sensed with a solid-state transducer—a silicon chip chemically etched so that physical pressure changes its electrical characteristics in a known way. When the sound of rushing blood drops off, the sensor measures the diastolic pressure.

A problem with home blood-pressure monitors is that their accuracy depends on exact placement of the microphone over the main artery. Misplacing the microphone just 15° along the circumference of the arm could make the reading inaccurate, says Glen Weinberg, manager of medical product planning at Sharp (Paramus, N.J.).

Some new monitors replace the microphone with a more flexible approach. Instead of listening for the blood, these oscillometric systems figure when to make the two readings by monitoring the small pressure waves that result when the artery expands and contracts with blood. "With the oscillometric unit, as long as the cuff and the pressure transducer are within 30° of the artery, the readings will be reliable," says Weinberg.

Physicians generally praise the increased popularity of the home units,



Body sensors turn an exercise session into a video game. In Medcomp's Fitness Factory, heart rate sets conveyor speed: if your pulse is too fast, the bottles crash over the edge; too slow, and the tank overflows.

by Michael Wendland

though with some reservations. There is a danger that patients will rely too much on machines they operate and interpret themselves, says Dr. Sampson Kpadenou, director of the Rochester (Mich.) Weight Control and Health Center. Kpadenou tells of one patient, a marathon runner in excellent health, whose home blood-pressure machine consistently showed a dangerously high diastolic reading. "By the time he came to see me, he thought he was dying," recalls Kpadenou. "Actually, his pressure was fine—he just hadn't used the machine properly. You can't imagine the needless stress he underwent." Worse than a false alarm, however, is a false sense of security. "What frightens me," says Kpadenou, "is that there are probably seriously hypertense patients out there who are checking out okay because they're not using the machine properly."

Another popular item is the pulse meter, particularly attractive to athletes, runners, and other fitness enthusiasts who want to monitor their heart's action during physical conditioning. In the most popular monitors, which cost about $30, a light-emitting diode (LED) shines an infrared beam onto the skin. As the blood vessels swell with each heartbeat, they turn darker and absorb more of the beam; between pulses, the blood becomes lighter, reflecting a stronger signal back to a photodetector. Thus, the rhythmic pumping of the blood is translated into a series of electronic pulses. These devices typically display a heart rate based on the average of the past six pulses.

Although convenient, infrared pulse meters are no more precise than manually counting pulses through the wrist for 15 seconds and then multiplying by four. Both methods measure the heartbeat indirectly, by sensing the resulting flow of blood through an artery. But heart patients and serious fitness enthusiasts can get a more exact reading with home electrocardiograph (EKG) devices, which detect the electrical signals that cause the heart to contract. The user touches a metal sensor, which can be built into a watch or baton. Because sophisticated circuitry is needed to distinguish the faint and brief (10-millisecond) electrical bursts, EKG pulse meters are much more expensive than infrared models. Insta-Pulse (Champlain, N.Y.), one of the first companies to market the devices, charges over $100.

In a more specialized application, portable glucose monitors let diabetics keep track of their blood sugar levels at home. The user puts a drop of blood on a reagent pad; a battery-powered LED illuminates the pad, and a photodetector senses the reflection. The higher the concentration of glucose, the less reflective the blood and thus the smaller the detector's electrical output. A microprocessor compares the reading with stored reference values, and the device displays the glucose level in standard units such as milligrams per deciliter. Although developed for personal use, these units are also finding use in some hospitals as a quick and inexpensive alternative to traditional blood chemical analysis. A typical device, manufactured by Lifescan (Mountain View, Cal.), sells for $170.

Perhaps less important medically—but nevertheless a potential lifesaver—are portable electronic "breathalyzers" that measure the concentration of alcohol in the blood. These units incorporate a semiconductor sensor whose conductivity increases in proportion to the concentration of alcohol vapor in the air blowing past it.

While small breath-testing devices have been around for a few years, most are too crude to be much more than novelties, with green, yellow, and red lights roughly indicating progressively higher degrees of intoxication. By contrast, the $70 Drivesafe, introduced last year by Canam Pacific (Calgary, Alberta), provides a quantitative display of alcohol level. The crackdown on drunk driving that has spread though the U.S. and Canada is helping to boost sales for the battery-powered machines, says Canam president Andre Comeau. He projects a steady market of 10,000 units a year.

Drivesafe's analog dial readout is calibrated to within 5% of a police breathalyzer, according to Comeau. But to attain such a close match the user must exhale completely, pushing out the alcohol-rich air at the bottom of the lungs. Too short a blow gives a falsely low reading.

Several products are being promoted as biofeedback devices that are supposed to teach their users how to control the stress that causes headaches. The $109 Antache from Biosig Instruments (Montreal), for example, consists of a headband wired with electrodes, and a set of stereo earphones. The electrodes pick up the electromyograph signal (EMG) produced by nerve firings in the forehead muscles; the unit feeds a tone into the headphones with pitch that increases with the level of muscle activity (i.e., tension). By trying to control this audible cue—perhaps by conjuring up peaceful mental images—users can learn to relax muscles they didn't know were tensed, thereby reducing headaches.

Similar biofeedback principles underly a $200 system called Bodylink from Medcomp Technologies (Armonk, N.Y.). The unit digitizes readings from various sensors attached to the body—monitoring such things as brain waves, blood pressure, skin temperature, and muscle activity—and feeds the data into a Commodore 64 computer. These body signals control the action on a TV screen, much as a joystick does in a video game.

In addition to programs for stress management, Bodylink can be used to guide the fitness enthusiast toward more productive workouts. For example, a pulse meter can be worn while pedaling a stationary bicycle; on the screen, computer-generated imagery drifts by, punctuated by graphic exhortations to work harder (if the pulse rate is lower than it should be for maximum aerobic effect), or warnings to slow down (if you are exceeding sensible limits based on your age and general physical condition).

Medical research has validated biofeedback; recent studies show that as many as 75% of headache sufferers can find relief through EMG biofeedback therapy, according to neurologist Seymour Diamond of the University of Chicago medical school. But Diamond, who operates the country's largest clinic for headache sufferers, doubts that the average person can learn biofeedback without professional guidance. He sounds a cautionary note that applies to much of the do-it-yourself healthcare field: "You need a skilled therapist to take you through the method if it's going to be effective," he says. "You can't get that on your own or by reading a guidebook." □

Michael Wendland, an investigative reporter for WDIV-TV *in Detroit, is also a freelance writer and author.*

ULTIMATE WAR GAMES

Laser battlefield provides realistic military training

In the hostile desert between Los Angeles and Las Vegas, U.S. Army troops are undergoing the most realistic battle training short of war. Exposed to lasers that substitute for bullets, as well as authentic aerial and electronic warfare threats, they are experiencing a battlefield environment unequaled by any other simulation. In addition, mobile video teams on site provide immediate feedback that enables the forces to determine how well they use their fighting assets in the din of simulated armored battle.

The 1000-square-mile facility at Fort Irwin, Cal., is dedicated to something that no commander, weapons operator, or soldier can afford in Wellington's "fog of war"—the luxury of mistakes. Any miscalculation on the battlefield is cured quickly, usually by the enemy. Errors on the instrumented plains and dry lakebeds of the National Training Center (NTC) are cured almost as fast, but painlessly, by video critique, computer graphics, and the monitoring of communications networks.

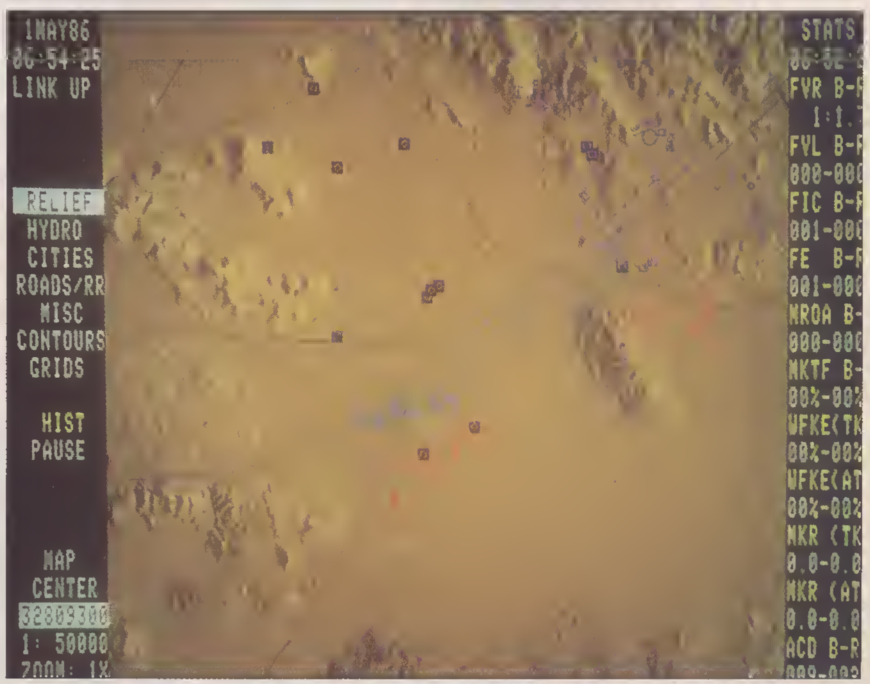
The purpose of the NTC, which is operated in part by Amex Systems (Chula Vista, Cal.), is to train visiting army units in responding to aggression of the type expected from Warsaw Pact nations. The premise is that a smaller force, which is better coordinated and supported and shows initiative and flexibility, can prevail against a larger, more centralized and inflexible adversary.

At the heart of the training is the Multiple Integrated Laser Engagement System (MILES), which enables weapons operators and soldiers to be "killed" and yet live to fight another day. Built by Loral Electro-Optical Systems (Pasadena, Cal.), MILES uses solid-state gallium arsenide lasers that emit eye-safe infrared light to simulate actual weapons over the complete range of the Army's inventory. A microphone activates the laser each time a blank round is fired, producing a laser pulse coded according to the weapon that fires it. That coding is recognized by detectors carried by vehicles (on fabric belts) and personnel (on harnesses that resemble conventional Army packs).

When a laser pulse strikes a detector, associated software that contains the kill probabilities for various weapons striking different targets determines whether the shot was a kill, a hit, or a near miss. Detector systems on individual soldiers, for example, have a hit/near-miss/kill alarm mounted close enough to the left ear to be annoying when triggered; when it detects the properly coded laser pulse beyond threshold level, the system indicates a hit by beeping intermittently. Once killed, the infantryman removes a key from his weapon and shuts the alarm off, thus preventing his MILES transmitter from producing laser pulses, and rendering himself a support liability instead of a combat asset.

Crucial to the system's success in training is the accuracy of the hit/kill ratios. Studies have shown that the MILES-equipped M-16A1 rifle, for example, has a hit probability within 10% of that of live ammunition. Other ratios are less certain. For example, the Army has programmed the Soviet Sagger antitank missile at a 70% hit/kill probability; its performance in the Sinai desert during the 1973 Arab-Israeli war, however, suggests a lower figure.

In some cases, vehicles can take a number of hits before being put out of action. And, of course, the coded pulse must correspond to a weapon to which the laser-illuminated vehicle is vulnerable; otherwise, no signal can be processed. An armored tank cannot be killed by a MILES M-60 machine gun, for example, although crewmembers standing in an open hatch can be removed from action by a sharpshooter or machine gunner. MILES also takes into account ammunition supply, using an inherent delay loop to simulate artillery or missile loading time. Hence, an individual soldier can run



Graphic display of simulated battle at the National Training Center shows two echelons of red forces (bottom and right) massing to attack the blue forces' flank, while blue artillery (blue lines) misses its target.

by Quinn Johnson

out of ammunition or be killed while waiting for his weapon's reloading cycle.

The system isn't entirely foolproof; its laser beam can be weakened by fog or rain (rare conditions at the desert base). And soldiers can protect themselves from the MILES signals behind foliage too light to do the job against real bullets. However, human observer/controllers patrolling the battlefield can counter such situations. Not only do they specify kills caused by mines, artillery, and chemical warfare; they can also use "God guns"—small, battery-powered MILES transmitters that can be adjusted to emit the laser signal of any weapon in the inventory—to "resurrect" soldiers wrongly killed in laser battle, and to kill those who avoided death by taking advantage of the simulation's characteristics rather than by using battle savvy.

In one exercise, battalion task forces advance through a live-fire range that simulates advancing or retreating waves of Warsaw Pact men and materiel. The troops must shoot down computer-driven targets that pop up at various distances and stay up for only brief periods of time. Remotely piloted scale Mig-27s, built by Continental RPVs (Barstow, Cal.), and simulated Sagger antitank missiles harass the trainee troops and represent well the confusion and heat of battle.

Laser equipment provides a realistic simulation of a helicopter's ability to fire air-to-ground missiles.

The main feature of the training, however, is a force-on-force encounter using MILES weaponry. The "home" team, based at Fort Irwin and designated the "Red" force, is the 32nd Guards Motorized Rifle Regiment. Its task is to defend its turf against visiting units. The 32nd fights within the constraints of Warsaw Pact nations' doctrines and tactics, which have been gleaned largely from captured Soviet manuals and updated as new Soviet tactics emerge. Massive attacks, in which a commander could lose a large portion of his force, are the norm. This trading of men and materiel for terrain is the basic concept underlying the centralized, large-scale formations of the Soviet bloc. Sheer numbers of troops make it possible. Mimicking the real thing, the 32nd Guards often enjoy a 6-to-1 manpower advantage over their trainee opponents.

The visiting "Blue" forces—battalion task forces that, including support units, number about 1000—depend on the doctrine of force multiplication, whereby sophisticated command and weapons systems in the hands of highly trained personnel successfully take on much larger forces. The key to force multiplication is a reliance on technological superiority, "smart" weapons, well-trained personnel, and good communications.

Since the basic purpose of the exercise is to train battlefield commanders and their troops to use all the resources at their disposal in time of war, both teams of combatants can call in air power, courtesy of the U.S. Air Force. Red aircraft are, in reality, F-4 fighters from nearby George Air Force Base, while F-16s and A-10s from the same base represent Blue airpower. Pilots fire live ammunition at computer-controlled pop-up targets. The air warriors also deliver guided Maverick missiles and bombs weighing up to 2000 pounds. In addition, Loral is developing a MILES-compatible air-to-ground laser engagement system for the aircraft.

The forces are subjected to subtle harassment as well as brute-force pummeling. Fort Irwin's Electronic Warfare (EW) detachment performs such electronic intelligence tasks as intercepting the radio traffic of the Blue forces and jamming selected trainee radio networks. The tactical tools include the XM-330 jammer, which can monitor up to 15 frequencies per second. At the first indication of a Blue radio transmission, the jammer blocks the frequency in a manner that suggests problems with the radio's hardware.

The EW detachment also uses Ground Radar Emissions Training Aviators (GRETAs), which simulate threats to Blue aircraft. When a GRETA signal locks onto an attacking aircraft, a cockpit warning device tells the pilot that an antiaircraft missile has been or is about to be launched, or that his plane is being tracked by radar-aimed artillery. The pilot must take action immediately, by dispensing aluminized chaff to obscure his craft's radar signature and/or by undertaking evasive flight maneuvers. Pilots encountering a threat from an infrared heat-seeking missile may jettison decoy flares as they maneuver away from the simulated antiaircraft fire from the ground.

Overseeing all the action is the NTC Operations Center. There, observer/controllers monitoring transponder radios on up to 500 vehicles or troops can plot vehicle locations and report whenever a specific MILES event occurs—such as the firing of or taking of fire from a MILES transmitter. The Operations Center's computer uses a timing algorithm to determine which vehicles and troops are engaging each other. Delays, built into the MILES, simulate the time the various weapons require to reach their targets. The software, taking these lags into consideration, matches the unit being fired upon and the firing transmitter by precise timing. Thus, the Operations Center can monitor the battle in real time. In addition, special transponders signal the Operations Center when the A-10 aircraft are on station, thereby allowing computer tracking. Further surveillance aid comes from a training

version of the Maverick missile mounted on the A-10s, which contains a video recorder to gather precise battle damage assessments.

The purpose of the analysis is to gain material for "after action reviews." The senior observer/controller conducts the main review in a specially fitted mobile theater van near the battle site. The other observer/controllers provide their own reviews for individual battle groups, down to the company and platoon level. All are held in the field and take place three to four hours after the engagements.

Observer/controllers also compile a "take-home package" for each task force after its 14-day rotation at Fort Irwin. This consists of up to 70 hour-long, broadcast-quality videocassettes, along with selected radio transmissions and reports from observer/controllers. This package enables the visiting unit to review its strengths and weaknesses at its home post.

NTC has a few weaknesses of its own. Because of space limitations, the facility cannot subject forces to long-range missiles. It teaches troops the techniques of fighting desert wars, and is thus more suited to Middle East combat than European action. The simulated encounters do not include anti-guerilla warfare. And according to a report just released by the General Accounting Office (GAO), the Army has not yet managed to realize the NTC's full potential because it has been unable to use the center's data to assess the effectiveness and efficiency of its organizations and weapons systems.

Nevertheless, the GAO report applauds much of the effort at Fort Irwin. "The Army has met its objective of providing realistic training," it asserts. "Several unit commanders stated that as a result of their NTC experience, they were training their soldiers under more realistic and rigorous conditions than they had in the past."

The highly realistic simulation is not restricted to Army war games. Systems similar to MILES are now available for training personnel in law enforcement agencies and private security forces. There is even a small but growing recreational market for laser weapons simulators that can be used in games such as "king of the hill" and similar tests of civilian outdoorsmanship. □

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COMPUTING IN COMFORT

Proper furniture and a few quick fixes can save your back

As more people spend more of their time sitting in front of computers, stiff necks and sore backs are proliferating. The reason is that little thought is given to setting up a computer for the user's maximum comfort.

As a relatively recent addition to office decor, computers are usually set up on any available desk or table. But standard office furniture is simply not built to accommodate computers. The shallow typewriter extensions common on secretarial-style desks aren't deep enough to hold most microcomputers; as a result, the screen often ends up being placed to the left or right of the keyboard, forcing you to look sideways as you type. And though ordinary office desks are deeper, they are too high to permit comfortable typing. Unfortunately, much furniture sold specifically for computers does not work well either, apparently having been designed by people who do not work with computers.

Finding a comfortable location for your computer depends on several factors, including overall space available, typing position, noise, convenient access to disk drives and power switches, and screen glare (HIGH TECHNOLOGY, April 1986, p. 60). For three-piece microcomputers, the biggest problem is finding a place to put the main chassis. The most common installation—and the worst—is simply plopping the chassis, monitor, and keyboard on a table. This arrangement hogs far too much table space and often partially blocks access to the floppy disk drives. In the best configurations, only the keyboard and monitor rest directly on the table. Getting the main chassis off the table usually improves disk drive access and spares precious horizontal work space.

If you put the main chassis on a shelf above the table, the computer remains accessible for changing internal boards. In some offices, a sufficiently sturdy shelf will require custom installation. Low-cost, widely available computer tables from Bush (Little Valley, N.Y.) and O'Sullivan (Lamar, Mo.) also permit this configuration (even though the firms' advertisement photos show poor installation). The main chassis usually will not fit on a shelf below the table because it won't leave enough knee room; you can, however, put the computer on its side so it sits vertically on the floor. Floor mounting is easy and saves space but makes any work in the computer chassis awkward and could expose disk drives to accidental kicking, a real hazard for hard disks. Curtis (Peterborough, N.H.) and other companies make a small pedestal for holding the computer chassis vertically; yet another solution is to hang the computer off the end of a desk or table.

The keyboard should be at a comfortable typing height, usually 27 inches off the floor, although individual needs may vary. The height of some computer desks can be adjusted, a handy feature when many people must use one computer. Some tables have a separate adjustable cutout for keyboards—a better idea in theory than in practice. Such cutouts cannot be adapted to keyboards of different sizes and, more important, lack flat horizontal space at an appropriate height for a mouse. The computer table should be deep enough to leave 4–5 inches of space for your palms to rest on the table in front of the keyboard and to allow space for setting up your monitor.

Optimum monitor height is a matter of personal preference. Most people are accustomed to looking downward at papers on their desk, and thus may prefer a low monitor position. The monitor can sit on the table, tilted up with either a pedestal or a small wood block to face you squarely. Most commercial pedestals are adjustable, an unnecessary feature for computers used by only one person. A better, but more expensive, pedestal can lift the monitor off the table altogether, giving you more horizontal space behind the keyboard. Such pedestals also can lift the monitor to eye level, a position some people prefer.

Two-piece computers—those with a combined monitor/computer chassis such as the Compaq—need even deeper tables, since the monitor/chassis must sit behind the keyboard. Most such machines come with small folding legs to tilt up the screen. However, the legs usually aren't long enough; placing a piece of two-by-four lumber under them helps greatly. The Macintosh takes up the least space of the common computers, but it, too, should be tilted back to let the operator face the screen squarely.

Noise is another problem. Most computers have built-in fans whose continual whirring ranges from a modest whine to a nerve-wracking roar, and some hard disk drives squeak during operation. You can look for computers with either no fan or a quiet fan, but a modern microcomputer with multimegabyte memory and a hard disk usually needs to be cooled by a fan.

If you are willing to modify your computer, you can replace a noisy fan with a larger, slower-turning external fan connected by an air tube. If you wish to get more elaborate, you can place the fan in another room. Or you can put the computer chassis in a soundproof box. Such boxes usually have to be custom-made and are bulky and potentially awkward, particularly if you must open and close them to insert and remove floppy disks. Similarly, installing the computer itself in another room—with short cables through the walls to connect the keyboard, monitor, and floppy disk drives—is generally impractical. Some users leave the housing off their computers and disconnect the fan, which can work if enough air circulates through the chassis. A simple cloth wall hanging placed behind the computer can help cut the noise. Or if space permits, you can envelop the computer with sound-absorbent foam such as Sonex, a material made by Alpha Audio (Richmond, Va.) for lining recording studio walls. This treatment can help considerably, even if the computer is not completely enclosed.

Despite the extra effort of installing them, such modifications are worthwhile; think how convenient it was to write with pencil and paper on a comfortable table in blissful silence. □

by Cary Lu

Cary Lu is microcomputer editor of HIGH TECHNOLOGY.

PERSPECTIVES

Europeans join forces on technology

Nineteen European nations have banded together in a massive program to put themselves back in the international technology race. The program—called Eureka (European Research Coordination Agency)—now consists of about 70 cooperative commercial projects ranging from advanced fishing vessels to new-circuit design and factory automation; total funding has recently been estimated at slightly more than $2 billion. And even though Eureka faces some formidable obstacles to success, observers claim that the program could be Europe's best hope for at least partially reclaiming technology markets long lost to Japan and the United States.

Eureka's participants now include the 12 members of the European Economic Community (EEC) plus Sweden, Norway, Austria, Switzerland, Turkey, Iceland, and Finland. And it is likely that American and other non-European companies with European operations will also be permitted to participate.

Eureka was conceived slightly over a year ago by French president François Mitterrand. Although its main purpose is ostensibly to bring European nonmilitary technology into the same ballpark with that of Japan and the U.S., it was apparently galvanized by President Reagan's Strategic Defense Initiative ("Star Wars"). "Many European companies figured that they probably wouldn't get more than a few percent of the Star Wars funds," says Pierre-Henri Laurent, director of the international relations program at Tufts University (Medford, Mass.). "Eureka is their solution." Another contributing factor is the lingering fear that Star Wars could accelerate the brain drain that has already sent thousands of key European researchers across the Atlantic.

To be eligible for Eureka funding, each project must be supported by companies from at least two participating countries; a new secretariat based in Brussels will serve as project coordinator and clearinghouse. Specific funding arrangements are in many cases still pending; however, it is estimated that two-thirds of the funds will come from the companies doing the work, with the remainder coming from their governments. Great Britain has already committed itself to providing Eureka with about $70 million a year; West Germany will average some $20 million a year for the next decade.

Virtually no technology is being excluded from Eureka. Among the recently approved projects:

- A five-year program to develop wide-band telecommunications systems. Funded at $155 million, the effort is led by Britain's Plessey, France's Alcatel, and Italy's Italtel;
- Research on new gallium arsenide chips, to be conducted by Thomson in France and GEC in Britain;
- The design and construction of a new automated factory to produce electronic equipment. The plant is to be built by Spain's Inisel with support from France and Italy.

Other programs now under way focus on software, automotive ceramics, fiber optics, hazardous waste control, medical diagnostics, and crop genetics.

Eureka resembles other Pan-European technology programs. The four-year-old, $1.2 billion Esprit (European Strategic Program for Information Technology), for example, targets the joint development of new telecommunications systems, software, and circuits by EEC companies. One fundamental difference, however, is that Esprit is a "precompetitive" effort geared more to research than to commercial development. Another example is EEC's Cube (Concertation Unit for Biotechnology in Europe), a sort of bio-Esprit.

Therein may lie a problem, says Francis S. Urbany of the U.S. Commerce Department's National Telecommunications and Information Administration, who cites "a lot of competition for what seem to be limited resources." Tufts's Laurent agrees: "Certainly there's a potential for conflict between Eureka and these other programs, especially with respect to funding. In fact, many of the Eureka projects are offshoots of programs that began under Esprit. It's going to require a lot of coordination, and that's one of the advantages of having Eureka based near EEC headquarters in Brussels."

Other problems include the potential domination of the program by the wealthier nations, and still-undetermined commercialization rights. It is assumed that EEC member companies will work within Community guidelines and regulations to forge specific marketing details. "But if one or more of the companies are non-EEC members, they may not necessarily feel bound by such rules," says Laurent.

BOB DAHM

Despite doubts in some quarters, Eureka appears to be surrounded by a glow of cautious optimism. One encouraging sign has been the startling speed—serious discussions began only about a year and a half ago—with which Eureka has charged into action. Observers also note that European companies have already demonstrated (through the Concorde supersonic transport and the European Space Agency, for example) that they can work together, even if their governments sometimes can't.

"No one believes that old national hostilities will ever be eliminated entirely," says Laurent, "but you're talking about leading-edge companies that make up the European elite. If they ever hope to recover some of their high tech export power, it's in their best interests to put differences aside." □

—H. Garrett DeYoung

Jammers escalate radar road wars

The latest entries in the technological battle of the highways are radar jammers—transmitting devices that foil police radar detection systems by either scrambling the signal or sending a preset reading to the radar gun. Sales figures for the jammers are not available, but Oregon Microwave (Portland, Ore.) claims is has sold 40,000 jammer kits in the past 18 months—at $55 each—to do-it-yourselfers.

Police radar guns are based on the fact that the frequency of an electromagnetic wave emitted or reflected from a moving object varies with the speed of the object (the doppler shift). This effect is usually illustrated by the changing pitch of a whistle on a moving train as it approaches, then recedes from, the listener. The guns transmit a signal in either of two frequency bands, X or K, depending on the brand of the gun. When the signal is reflected from a moving car, the frequency is shifted by about 30 Hz for an X-band radar and about 70 Hz for a K-band radar for every mile per hour the car is traveling. The shifted signal is received by the radar gun, which then computes the speed of the car.

While the conventional radar detector is simply a passive receiver, the jammer uses a transmitter mounted behind the vehicle's front grille to broadcast the signal and a microprocessor to control the pulse transmission rate. To be sure of jamming a police radar, the device needs two transmitters, one for each of the two frequencies used by police radar guns. Some of the more sophisticated jammers operate in conjunction with a radar detector, so that the jammer is automatically switched on once the detector picks up a radar signal. The most advanced versions allow a driver to select the percentage of the car's actual speed to be transmitted. In this mode of operation, there is no need to adjust the jammer for different speed limits.

Jammers are designed to foil the radar in either of two ways. One type scrambles the message by emitting signals of several different frequencies; the gun cannot sort out the one reflected from the car, and so cannot determine its speed. The second, more sophisticated jammer lets the driver set a desired speed; the device then emits a signal that is shifted in frequency to correspond to that speed. If the emitted signal is stronger than the one returning from a radar gun, the gun will read only the preset speed.

Not surprisingly, highway police have responded with a variety of new speed-detection techniques, in addition to old standbys like visual monitoring with unmarked cars and aircraft. New weapons include instant-on radar (which gives the driver less time to slow down) and an electronic time-and-distance stopwatch that allows the police officer to determine speed simply by tracking the car for a short distance; the watch has recently been adopted by the Massachusetts State Police. Also in Massachusetts, the Department of Public Works is using a new method to measure speed on the highways: two sensors consisting of wire loops set into the pavement 16 feet apart. The technique—which makes detectors and jammers useless—was originally designed to count vehicles, but could soon rank with radar guns as important speed-enforcement devices.

Besides police countermeasures, there are other drawbacks. One is the cost: devices that transmit on both bands are priced from $235 (for a kit offered by Remote Systems) to $345 (for the Evader from Automotive Outfitters in Hicksville, N.Y.). Oregon Microwave sells a 300-milliwatt device that transmits on the X band for $210 and a 150-mW K-band transmitter for $235.

An even bigger problem for would-be speeders is the fact that jammers are illegal in every state. Penalties include fines of up to $10,000 and a prison term. And while the passive radar detectors are legal in most states, the signal-transmitting jammers require FCC licensing; it is unlikely that the agency will approve a device clearly meant for circumventing police radars. The only reason the jammers are available at all, in fact, is that they can serve a legitimate purpose: the calibration of police radar guns. □

—Salvatore Salamone

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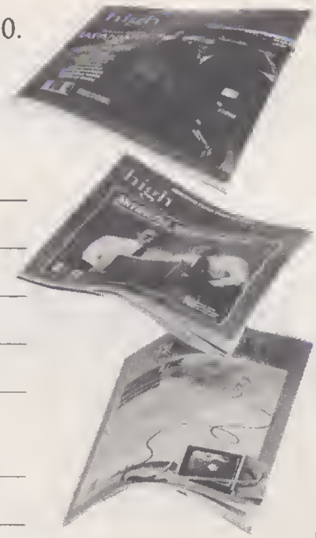

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TECHSTARTS

Video Workshop:

EDIT YOUR OWN VIDEOTAPE

While the camcorder's advent has put video recording within the grasp of millions, it still takes professional-quality editing equipment to create a polished videotape from rough footage. The Video Workshop is a chain of do-it-yourself editing and duplicating centers, where businesses and individuals can rent professionally equipped half-inch-tape editing studios and sound booths by the hour. The centers also rent cameras and other production equipment, and some even have systems that customers can use to create their own computer graphics and animation. With more than 30 centers franchised nationwide, the company currently has no direct competitors. It is targeting small and medium-size businesses that want to produce sales, marketing, and instructional videos, as well as individuals who want to smooth the rough edges off their home-made videos.

Financing: Seed capital was raised internally.

Management: David Bawarsky (founder and president) produced videos for the real estate industry. Ken Chivers (director of franchise marketing) headed franchising programs for Kindercare Daycare Centers, Lums Restaurants, and Congress International, a motel chain.

Location: 2400 Cypress Creek Rd., Suite 205, Fort Lauderdale, FL 33309, (305) 491-1244.

Founded: October 1983.

Syntellect:

AUTOMATING CUSTOMER SERVICE

Syntellect's computerized phone system automatically answers routine questions, says president S. Thomas Emerson.

The next time you call your bank to make a routine inquiry about current interest rates, you may end up talking to a computer. Syntellect has developed a system called Infobot that prompts callers to ask questions by pressing numbers on push-button phones; it then gives answers in a computer-generated voice. The system can be tied into a company's existing customer service database with an installation procedure simple enough to be performed by a nonprogrammer, claim the developers, because it incorporates artificial intelligence techniques. Syntellect is targeting financial, transportation, utility, and manufacturing companies with large customer service departments.

Financing: $8.7 million in venture capital from investors including Hambrecht & Quist, Welsh Carson Anderson & Stowe, Advanced Technology Development Fund, SunVen Partners, Michigan Capital & Services, DeMuth Folger & Terhune, El Dorado Investments, and Rainier Venture Partners.

Management: Founders S. Thomas Emerson (president and CEO), Harwood Shepard (vice-president of marketing), and Robert S. Wallin (vice-president of technical operations) defected from Periphonics, a maker of phone-activated computerized speech systems. Emerson was Periphonics' co-founder, president, and CEO, Shepard was a marketing and technical specialist, and Wallin was VP of eastern operations.

Location: 21200 N. Black Canyon Hwy., Phoenix, AZ 85027, (602) 264-5900.

Founded: November 1984.

Formative Technologies:

DIGITIZING HANDMADE DRAWINGS

Companies such as utilities and construction firms amass large libraries of maps and blueprints that must be continually updated to reflect additions and modifications. Although the most recent drawings may have been generated electronically, staff engineers also often work with hand-drawn copies that are decades old. Formative Technologies (Formtek) has developed a scanning technique for digitizing these prints without the laborious hand tracing (with an electronic stylus) necessary to enter drawings into most other computer graphics systems. By translating widely varying sizes and scales into a single format, the system also allows engineers to edit and combine old prints just as they do electronically generated ones. Formtek is targeting public utilities, civil engineers, and corporate engineering and maintenance departments. Competitors are all start-ups, such as Skantek and Optigraphics.

Financing: $11 million in venture capital from the corporate venture funds of Westinghouse, Bechtel, Foster Industries, Koppers Co., and investment firm SRK Management.

Management: Founders Charles M. Eastman (executive VP and chief scientist) and Samuel Leinhardt (executive VP and COO) came from Carnegie-Mellon University, where Eastman was founder and director of the CAD-Graphics Laboratory and Leinhardt was a professor at the Graduate School of Industrial Administration. Robert J. Shea (president and CEO) was senior VP of corporate development for Paradyne, a data communications firm.

Location: 5001 Baum Blvd., Pittsburgh, PA 15213, (412) 682-8000.

Founded: March 1983.

ART CHRISTIANSEN CAMERA ARTS

ANALYTICAL DEVICES EXTEND THEIR REACH

Demand is rising as industries boost process control and pollutant monitoring

Analytical instruments such as mass spectrometers and chromatographs provide information about the composition of various samples. In particular, these instruments are being increasingly used to detect the presence of chemicals and other compounds in such diverse locations as toxic waste sites, wine vats, and semiconductor fabrication plants. The world market for mass spectrometers and chromatographs should be about $1 billion this year, with a long-term growth rate projected at 25% per year, according to Hambrecht & Quist (San Francisco).

Demand for such equipment is spurred by several factors. Environmental regulations require closer monitoring of pollutants. Consumers are pressing for more complete information on the chemicals in food, water, and manufactured products. Corporate monitoring of the use and levels of chemicals in the workplace is increasing in order to refine industrial processes, improve manufacturing efficiency, and prevent mishaps that could lead to lawsuits. In addition, the emerging biotechnology industry requires high-quality purification, separation, and analysis of biological compounds.

The technology of measurement is advancing in response to these needs. Improvements include the linking of instruments to personal computers, the emergence of on-line and remote sensor-based measurement, and the ability of software to take over complex measurement functions. These capabilities are making instruments easier to use and applicable outside the lab, including previously hard-to-reach or dangerous settings.

by Nancy E. Pfund

Large, diversified companies such as Perkin-Elmer, Varian Associates, SmithKline Beckman, and Hewlett-Packard play dominant roles in this industry, but much of the technological innovation is found in smaller companies that exploit particular niches. Among these firms, Finnigan (San Jose, Cal.) and Dionex (Sunnyvale, Cal.) are well positioned to respond to technological and market trends.

Finnigan (OTC: FNNG) is the leading manufacturer of mass spectrometers, which are widely used in government and private laboratories to implement environmental laws. The company holds about 40% of the world market for such devices, but its earnings have suffered recently because of new-product delays and foreign exchange problems relating to plant operations in West Germany. However, product-development efforts over the last two years have positioned Finnigan to move ahead on several fronts. For example, the company has taken a jump on its competitors by investing heavily in software improvements that have made its products less expensive, more reliable, and more efficient. The firm is also moving to address measurement needs in biotechnology, process control, and metal analysis, and has expanded its distribution channels into previously untapped markets by selling some of its products under Perkin-Elmer's logo.

Finnigan's revenues are projected to be $92 million this year, up from $80.6 million in 1985; however, 1985 profits of $4 million and 85¢ earnings per share will drop in 1986 to an estimated $2.5 million in profits and an earnings per share of 50¢. The company's overall position should improve in 1987, when revenues should reach $115 million, with profits of $7.7 million and $1.40 earnings per share.

Dionex (OTC: DNEX) pioneered the commercial use of ion chromatography in 1975 and now controls 80% of this market. Ion chromatographs, which separate and detect amino acids, metals, and organic and inorganic ions in a sample, are used for such applications as testing lake water for acid rain damage and monitoring for process water impurities in the semiconductor and nuclear power industries. Dionex's strengths include the exclusive license it holds to a Dow Chemical patent on one type of ion chromatograph technology and its product line of automated, rapid-sampling instruments that can be applied in areas formerly requiring manual measurement. Last year Dionex introduced a chromatograph that is capable of making automated, continuous process-control measurements on the factory floor; the company's current strategy is to develop a more diverse array of products that will increase its presence in high-performance liquid chromatography markets such as biotechnology, pharmaceuticals, and food.

Dionex's fiscal 1986 earnings were $1.60 per share, based on profits of $7.4 million and revenues of $45 million. Earnings last year were $1.31 per share, stemming from $6 million in profits and $35 million in revenues.

A number of private companies also merit attention as possible future investment opportunities. **Zymark** (Hopkinton, Mass.) makes lab robots to automate sample handling and preparation. **Nelson Analytical** (Cupertino, Cal.) offers several software packages that facilitate chromatography analysis and integrate the various computers and instruments in a laboratory. **Xertex** (Menlo Park, Cal.) specializes in dedicated process instruments for particular substances and microprocessor-based level- and density-measurement instruments that help prevent tanks from exceeding their intended capacity. **Mattson Instruments** (Madison, Wis.) is a technological leader in the fast-growing market for fourier-transform infrared spectrometers. These devices are especially useful in distinguishing molecular isomers—compounds having the same mass but different chemical properties such as toxicity; mass spectrometers alone cannot always do the job. □

Nancy E. Pfund is a chemical technology analyst with Hambrecht & Quist (San Francisco), a venture capital and investment banking firm.